PATENT ABSTRACTS OF JAPAN

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(71)Applicant : NIKON CORP
(72)Inventor : SUWA KYOICHI

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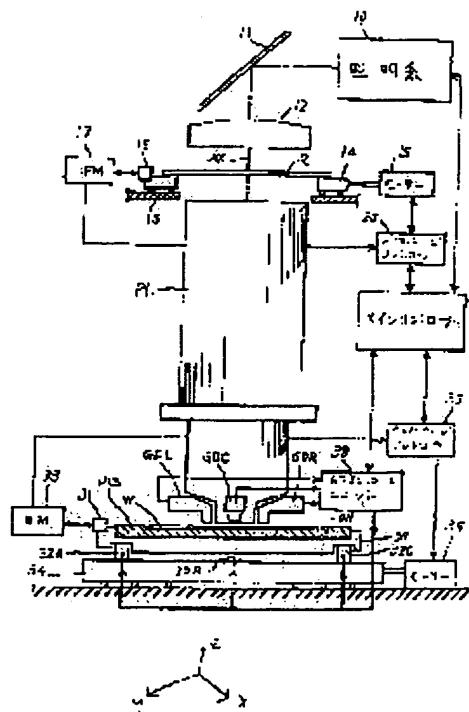
(54) FOCUS AND TILT ADJUSTING SYSTEM FOR LITHOGRAPHY ALIGNER, MANUFACTURING DEVICE OR INSPECTION DEVICE

(57)Abstract:



PROBLEM TO BE SOLVED: To realize a focus and tilt adjusting system which enables high- precision focus control and high precision tilt control by a method wherein the position of the principal surface of a substrate in the z-direction is detected in the scanning direction, a direction intersecting the scanning direction, and a direction intersecting the scanning direction from the image forming direction respectively, and a focus of an image projected onto the substrate is adjusted basing on the detection values.

SOLUTION: Forcus detecting systems GDL and GDR are each equipped with focus detection points positioned in front and at the rear of an imaging field, respectively, with respect to the direction of a scanning movement of a wafer W in scanning projection aligner. Seeing from above the surface (XY plane) of a wafer W, a focus detecting system GDC is equipped with a detection point located in a non-scanning direction vertical to the scanning direction of the imaging field of a 1 4 reduction projection lens PL. Z actuators 32A, 32B, 32C are driven by an optimal distance by an AF control unit 38 basing on the detection data supplied from the focus detection systems GDL,

GDR and GDC.

CLAIMS

[Claim(s)]
[Claim 1 A scanning exposure device comprising:
(a) An image formation system for projecting an image of a pattern of a mask on a substrate with an image formation view.
(b) A scanning mechanism for moving said mask and said substrate to a scanning direction to said image formation system.
(c) A regulatory system for adjusting a focus of an image projected on said substrate.
(d) It is a detection area to the 1st position.

[Claim 2 In the scanning exposure device according to claim 1, said scanning mechanism, A scanning exposure device having a synchronous drive system for moving said mask stage and said substrate stage with a velocity ratio corresponding to a mask stage for holding said mask, a substrate stage for holding said substrate, and projecting magnification of said image formation system.
[Claim 3 The scanning exposure device comprising according to claim 2:
A suction part for said substrate stage to draw a rear face of said substrate.
An auxiliary plate part surrounding when said substrate is supported by said suction part height almost equal to the surface of said substrate said substrate.

[Claim 4 When a shot region of said substrate exposed with a pattern of said mask is in a periphery of said substrate in the scanning exposure device according to claim 3, A scanning exposure device, wherein said 2nd detection system and said 3rd detection system are arranged so that at least one detection area can detect a position in a Z direction of the surface of said auxiliary plate part among said detection areas.
[Claim 5 In the scanning exposure device according to claim 4, said 1st detection system, this -

- a Z direction position error value of the surface of said substrate to a predetermined standard Z position about the 1st detection system. and -- this -- generating one side of a Z direction position error value of said auxiliary plate part to a predetermined standard Z position about the 1st detection system, said 2nd detection system, this -- a Z direction position error value of the surface of said substrate to a predetermined standard Z position about the 2nd detection system. and -- this -- generating one side of a Z direction position error value of said auxiliary plate part to a predetermined standard Z position about the 2nd detection system, said 3rd detection system, this -- a Z direction position error value of the surface of said substrate to a predetermined standard Z position about the 3rd detection system -- and -- this -- a scanning exposure device generating one side of a Z direction position error value of said auxiliary plate part to a predetermined standard Z position about the 3rd detection system.

[Claim 6 Said predetermined standard Z position concerning on the scanning exposure device according to claim 5 and said 1st detection system, A scanning exposure device characterized by a difference between said predetermined standard Z positions being detected by proofreading when said predetermined standard Z positions about said predetermined standard Z position about said 2nd detection system and said 3rd detection system differ mutually.

[Claim 7 In the scanning exposure device according to claim 4, by a case where a scanning direction of said substrate is the direction of Y. When a direction which intersects perpendicularly with each of said direction of Y and said Z direction is the direction of X, said 1st detection system, A scanning exposure device having the 1st focus detector of a multipoint type which has two or more detection areas, crossing said two or more detection areas to the range of size in said direction of X of an image formation view of said image formation system, and having become a single tier in accordance with said direction of X on said substrate.

[Claim 8 In the scanning exposure device according to claim 7, said 2nd detection system, Have two or more 2nd focus detectors, and said 2nd focus detector, Equip both sides in said direction of X with a detection area among said two or more detection areas used as a single tier of said multipoint type of the 1st focus detector, and each of said 2nd focus detector, A scanning exposure device characterized by detecting a Z direction position of one of said surface of said substrate and said auxiliary plate part separately in each of said detection area.

[Claim 9 In the scanning exposure device according to claim 8, said 3rd detection system, Have two or more 3rd focus detectors, and said 3rd focus detector, A scanning exposure device, wherein it is provided in both sides in said direction of X of said image formation view of said projection system and each of said 3rd focus detector detects a Z direction position of one of said surface of said substrate and said auxiliary plate part separately in each of said detection area.

[Claim 10 A projection aligner comprising:
(a) An image formation system for projecting an image of a mask pattern on a substrate in the projection view fields.
(b) A movable stage mechanism for moving in the direction which crosses in the direction of X, and the direction of Y, and positioning said substrate about an image of said projected mask pattern.
(c) A regulatory mechanism for adjusting a focus of an image of a mask pattern projected on said substrate.
(d) It is a detection area to the 1st position.

[Claim 11 In the projection aligner according to claim 10, said 1st detection system, Have two or more 1st focus detectors that have two or more detection areas, and said two or more detection areas, A projection aligner, wherein it is a single tier in accordance with said direction of X in the range according to size in said direction of X of a projection view field of said image formation system and each of said 1st focus detector detects Z position of the surface of said substrate separately in each of said detection area.
[Claim 12 In the projection aligner according to claim 11, said 2nd detection system, Have the 2nd two focus detector and said 2nd two focus detector, A projection aligner, wherein it has two detection areas arranged at both sides of two or more of said detection areas used as a single tier of said 1st detection system and each of said 2nd focus detector detects Z position of the surface of said substrate separately in each of said two detection areas.
[Claim 13 In the projection aligner according to claim 12, said 3rd detection system, Have the 3rd two focus detector and said 3rd two focus detector, A projection aligner, wherein it is arranged at both sides in said direction of X of said projection view field of said image formation system and each of said 3rd focus detector detects Z position of the surface of said substrate separately in each of said two detection areas.
[Claim 14 In the projection aligner according to claim 13, said movable stage mechanism, When a fitting part for drawing a rear face of said substrate and said substrate are supported by said fitting part, A projection aligner, wherein it has an auxiliary plate part surrounding said substrate in height substantially equal to the surface of said substrate and the surface of said auxiliary plate part is detected by 1 of said 2nd two focus detectors, and 1 of said 3rd two focus detectors.
[Claim 15 By projecting some patterns of a mask on a photosensitive substrate through a projection system, and moving said mask and said photosensitive substrate to a projection view field of said projection system, Are a pattern of said mask a scanning exposure method transferred to said photosensitive substrate, and said method, (a) A step which attaches said photosensitive substrate to an electrode holder which has an auxiliary plate part surrounding

[height substantially equal to height of the surface of said photosensitive substrate said photosensitive substrate, (b) While having a step which reads a focal error of an exposure region of said photosensitive substrate where said some of mask patterns are projected and carrying out scanning movement of said electrode holder and said photosensitive substrate, Before said exposure region arrives at a projection view field of said projection system, it is read by said focal error of said exposure region, and said method, When an exposure region on the (c) aforementioned photosensitive substrate arrives at said projection view field, A step which detects a focal error of some [one] surfaces of said photosensitive substrate and said auxiliary plate part according to a focus detecting system for exposure positions which is distant from a projection view field of said projection system in the direction which intersects perpendicularly in said scanning move direction, and has been arranged, (d) Based on said focal error detected by said step (b) and (c), have a step which adjusts a focus between said projection system and said photosensitive substrate, and by it. A scanning exposure method, wherein a focal error of an exposure region on said photosensitive substrate is amended in the projection view fields of said projection system.

[Claim 16 In the scanning exposure method according to claim 15, said method is applied to a projection aligner, and said projection aligner has a projection system, and said projection system, A scanning exposure method having 20 mm or an operating range not more than it to the surface of said substrate.

[Claim 17 The scanning exposure method comprising according to claim 15:

Said method is [in / it is applied to a dipping-type projection aligner and said dipping-type projection aligner said photosensitive substrate.

Between transparent optical elements arranged at the image surface side of said projection optical system, it is a projection optical path.

[Claim 18 A scanning exposure method, wherein said projection optical system is provided with test working distance that thickness of a fluid between said photosensitive substrate and said transparent optical element of said projection optical system becomes 2 mm or less than it, in the scanning exposure method according to claim 17.

[Claim 19 In the scanning exposure method according to claim 15, said method, It is applied to a scanning exposure device and said scanning exposure device, A scanning exposure method, wherein it has a reflective refraction projection system, said reflective refraction projection system has an optical element for refraction, and an optical element for reflection and a transparent optical element is arranged in said scanning exposure device at the image surface side.

[Claim 20 A scanning exposure method, wherein said transparent optical element arranged at said image surface side serves as a prism mirror in the scanning exposure method according

to claim 19 and said prism mirror equips the surface of said photosensitive substrate with the parallel ejection surface substantially.

[Claim 21 Are said objective lens optical system the focusing device formed in a device which it has, and so that focusing can be controlled between the surface of a workpiece, and an objective lens optical system said focusing device, (a) Equip the 1st position with the 1st detection system provided with a detection area, and said 1st position, It is provided in the outside of a view of said objective lens optical system, and said 1st detection system, Have detected a position of said direction of focusing of the surface of said workpiece, and said focusing device, Equip the (b) 2nd position with the 2nd detection system provided with a detection area, and said 2nd position, It is provided in the outside of a view of said objective lens optical system, and an interval is opened and established from said 1st position, and said 2nd detection system, Have detected a position of said direction of focusing of the surface of said workpiece, and said focusing device, Equip the (c) 3rd position with the 3rd detection system provided with a detection area, and said 3rd position, Are provided in the outside of a view of said objective lens optical system, and from each of said 1st position and said 2nd position, open an interval, it is provided, and said 3rd detection system has detected a position of said direction of focusing of the surface of said workpiece, and said focusing device again, (d) Connect with said 1st detection system and said 2nd detection system, calculate a gap between said 1st focal position detected by said 1st detection system and a target focal position, and at the time of detection by said 1st detection system. A computer for memorizing said 2nd focal position detected by said 2nd detection system, (e) It has a controller connected with said computer and said 3rd detection system, When said field on said workpiece corresponding to said detection area of said 1st detection system positions within a view of said objective lens optical system by relative displacement of said workpiece and said objective lens optical system, A focusing device, wherein said controller is based without said calculated gap, said 2nd memorized focal position, and said 3rd focal position detected by said 3rd detection system and controls focusing of said objective lens optical system on said surface of said workpiece.

[Claim 22 When a workpiece and a view of an objective lens optical system receive in the direction of X, and the direction of Y mutually and move to them, Are focusing of said objective lens optical system in the surface of said workpiece the method of controlling, and said method, (a) A step which attaches said workpiece to an electrode holder which has an auxiliary plate part surrounding height substantially equal to height of the surface of said workpiece said workpiece, (b) While moving said electrode holder and said workpiece in the predetermined move direction, Before a local predetermined portion of said workpiece reaches a view of said objective lens optical system, Have a step which reads a focal error of said local portion of the surface of said workpiece, and said method, When said local portion of the (c)

aforementioned workpiece reaches said view, According to the 1st focus detecting system left and arranged from a view of said objective lens optical system in the direction which intersects perpendicularly in said move direction. A step which detects a focal error of some one surfaces of said workpiece and said auxiliary plate part, (d) Based on said focal error detected by said step (b) and (c), control focusing between said objective lens optical system and said workpiece, and by it a focal error of a local portion of said workpiece, A method amending with a view of said objective lens optical system.

[Claim 23 In a method according to claim 22, said method, . Have few operating ranges so that a detection beam of an oblique incidence light type focus detector may not be aslant led to the surface of said workpiece just under said objective lens optical system. A method applying to at least one of a measuring instrument for manufacture, a lithography exposure device, a drawing device, and the test equipment.

[Claim 24 an optical image formation system -- this -- a fluid in space between an optical image formation system and a photosensitive substrate, let pass and Are a mask pattern image a projection aligner for projecting on a photosensitive substrate, and said projection aligner, Have an assembly holding two or more optical elements of said image formation system, even if there are few said assemblies, it is dipped in said fluid by end part, and said projection aligner, It was attached to said end of said assembly, have an end optical element which has the end surface which counters said substrate and contacts said fluid, and Said end surface of said end optical element, A projection aligner the surface of said end of said assembly receiving mutually, being the same flat surface substantially, and preventing disturbance of said liquid flow by it.

[Claim 25 A method characterized by comprising the following of adopting a projection system and processing a molding section into a semiconductor wafer.

(a) Have a step which attaches said semiconductor wafer to an electrode holder, and said electrode holder, It has a wall provided at right angles to a periphery, and by this, a liquid layer can be formed on said wafer so that between the surface of said wafer and said projection systems may be in an immersion state, A scanning step which said method scans said electrode holder along the image surface of the (b) aforementioned projection system again, and performs scan exposure by this by projecting a molding section pattern image on said wafer through said projection system and said liquid layer.

(c) It has a step which amends either at least a focal error between the surface of said wafer, and the image surface of said projection system, or the tilt errors between said scanning steps by using a focus detecting system, Two or more focus detection points by which said focus detecting system has been arranged at the outside of the image surface of said projection system.

[Claim 26 A method, wherein said projection system is provided with resolution smaller than 0.5 micrometer in a method according to claim 25.

[Claim 27 A scanning exposure method characterized by comprising the following for transferring a pattern of a mask to a substrate through an image formation system.

Said scanning exposure method is provided with a step which provides the 1st detection system provided with the 1st detection area, and said 1st detection area, Are provided in the outside of an image formation view of said image formation system, and an interval is opened and provided in a scanning direction from said image formation view, and said 1st detection system, Have detected a position in an optical axis direction of said image formation system of the surface of said substrate, and said scanning exposure method, Have a step which provides the 2nd detection system provided with the 2nd detection area, and said 2nd detection area, Are provided in the outside of an image formation view of said image formation system, and an interval is opened and established in the direction which intersects said scanning direction from said 1st detection area, and said 2nd detection system, Have detected a position in said optical axis direction of the surface of said substrate, and said scanning exposure method, Have a step which provides the 3rd detection system provided with the 3rd detection area, and said 3rd detection area, Are provided in the outside of an image formation view of said image formation system, and further, from said image formation view, open an interval in the direction which intersects said scanning direction, it is provided in it, and an interval is opened and provided in said scanning direction from said 2nd detection area, and said 3rd detection system, A step which has detected a gap in said optical axis direction between a position of the surface of said substrate, and a target position and to which said scanning exposure method determines a target position of said 3rd detection system between exposure of said substrate again based on a detection result of said 1st detection system, and a detection result of said 2nd detection system.

A step which adjusts physical relationship between the surface of said substrate, and the image surface of said image formation system between exposure of said substrate based on a detection result of said 1st detection system, a detection result of said 2nd detection system, and a detection result of said 3rd detection system.

[Translation done.]

* NOTICES

DETAILED DESCRIPTION

[Detailed Description of the Invention
[0001]
[Field of the Invention Especially the invention in this application relates to the lithography exposure device (aligner) for transferring a circuit pattern from a mask or reticle to a sensitized substrate about manufacture of a semiconductor.
[0002]The invention in this application relates to the system (system) for detecting the tilt (namely, inclination) of said workpiece for detecting the focus on a workpiece (a wafer, a substrate, or a plate), i.e., work pieces, again. The system concerned can apply the state of the device for using laser and an electron beam, and manufacturing a workpiece, or carrying out image formation of the desired pattern to the surface of a workpiece, or the surface of a workpiece to a kind of a certain kind like the device for inspecting optically of device.
[0003]
[Description of the Prior Art In recent years, the semiconductor chip (DRAMs) of the DINA MIIKKU random access memory which has the integration density of 64 megabits is mass-produced by semiconductor manufacturing technology. Such a semiconductor chip is manufactured by exposing a semiconductor wafer, carrying out image formation of the circuit pattern, and piling up and forming the circuit pattern of ten layers or the layer beyond it by this, for example.
[0004]The lithography device used for manufacture of such a chip on the other hand now is an aligner for projection. In the aligner for the projection, it is reticle (.). The circuit pattern drawn on the chromium layer on a mask plate by or the pulsed light which has the wavelength of 248 nm from i line (wavelength of 365 nm) and the KrF excimer laser of a mercury-vapor lamp. By irradiating with said reticle, it lets the reduction optical image formation system (namely, reduction projection optical system) reduced to 1 4 or 1 5 pass, and is transferred by the regist layer of a wafer surface.

[0005]The projection aligner (aligner for projection) used for this purpose, According to the type of an image formation optical system, the group division is carried out in general at the thing (namely, what is called a stepper) using a step and repeat system, and the thing using the step and scanning method which has received attention recently.
[0006]A process is repeated in a step and repeat system. That is, in the process, whenever it carries out grade movement, when whose a wafer is the stepping method the pattern image of reticle uses a reduction projection lens system or the projection lens system of single magnification, it is projected on some wafers. Said reduction projection lens system is formed only from the optical material for refraction (lens element).
It has the circular image vision field.
The single projection lens system of magnification is formed from the optical material for refraction (lens element), the prism mirror, and the concave mirror.
It has the un-circular image vision field.
The shot region of a wafer or a plate is exposed to a pattern image by said image vision field.
[0007]A wafer is exposed by some images of the circuit pattern of reticle (for example, shape of a circular slit) in a SUTTEPU and scanning method. Some images of the circuit pattern of reticle are projected on a wafer through a projection optical system. Simultaneously, continuously, reticle and a wafer are fixed speed and move with the velocity ratio according to projecting magnification. Therefore, one shot region on a wafer is exposed by the image of all the circuit patterns on reticle in the scanning method.
[0008]For example, as described by 256 pages of SPIEVol.922 of "optical / laser micro lithography (Optical Laser Microlithography) (1988) thru or 269 pages a SUTTEPU and scanning method, After one shot region on a wafer is scanned and exposed, 1 step moving of the wafer is carried out, it is constituted so that the next shot region may be exposed, and it is constituted so that the effective image vision field of a projection optical system may be restricted to a circular slit. Although the projection optical system is indicated by United States patent (given to Shafer) 4,747,678th, it can be considered to be the combination of the optical element for two or more refraction, and the optical element for two or more reflection like.
[0009](It was given to Nishi) The United States patent is indicating an example of an aligner. In this aligner, the SUTTEPU and scanning method is performed by attaching the reduction projection lens for the steppers who have a circular image vision field. This U.S. gazette is indicating again the method by which the pattern image projected at the time of scanning exposure is transferred by the wafer when only the specified quantity makes the depth of focus (DOF) on a wafer increase.
[0010]in the field of a lithography technology, it is desirable that the semiconductor memory chip which has the integration density and accuracy of 1 giga or about 4 giga can be manufactured by exposure by light. The art exposed by light has long technical history, and

since it is based on the know how accumulated in large quantities, it is convenient to continue and use the art exposed by light. If the problem of the exposure technology by the electron beam instead of other or an X-ray technic is taken into consideration, it is effective to use the art exposed by light.

[0011]1 giga of memory chip is considered that the minimum linewidth (shape width) needs to be about 0.18 micrometer (micrometer). On the other hand, 4 giga of memory chip is considered that the minimum linewidth (shape width) needs to be about 0.13 micrometer (micrometer). In order to attain such a linewidth, the far ultraviolet ray which has wavelength shorter than 200 nm or it, for example, the far ultraviolet ray produced with an ArF excimer laser, is used, and, thereby, it can irradiate with a reticle pattern.

[0012](It has wavelength shorter than 400 nm or it) As an optical material of the glassiness which has suitable transmittance to a far ultraviolet ray, Quartz (S_iO_2), fluorite (C_aF_2), a lithiumfluoride (L_iF_2), a magnesiumfluoride (M_gF_2), etc. are generally known. Quartz and fluorite serve as an optical material of glassiness required in order to form the projection optical system which has high resolution in the range of a far ultraviolet ray.

[0013]However, supposing it makes the numerical aperture (NA) of a projection optical system increase and attains high resolution, making the size of a view increase, It is required to take into consideration the fact that the diameter of the lens element formed with quartz or fluorite becomes large, and manufacture of such a lens element becomes difficult as a result.

[0014]If the numerical aperture (NA) of a projection optical system is made to increase, depth-of-focus (DOF) deltaF will decrease inevitably. If the theory of Rayleigh of image formation is applied, generally depth-of-focus deltaF will be defined by wavelength, the numerical aperture NA, and the process coefficient Kf ($0<Kf<1$) as shown below.

[0015]deltaF=Kf- (lambda/NA ^{2})

Therefore, if 193 nm of wavelength becomes, wavelength is equal to the wavelength of ArF excimer laser light, the numerical aperture NA is set as about 0.75, and if the process coefficient Kf is 0.7, depth-of-focus deltaF in the atmosphere (air) will be set to about 0.240 micrometer. In this case, theoretical resolution (minimum linewidth) deltaR is expressed by the following equation which uses process coefficient Kr ($0<Kr<1$).

[0016]deltaR=Kr- (lambda/NA)

Therefore, under the state where it mentioned above, if process coefficient Kr becomes 0.6, resolution deltaR will be set to about 0.154 micrometer.

[0017]In order to improve resolution, while it is necessary to make the numerical aperture of a projection optical system increase as mentioned above, if a numerical aperture increases, it is important that it is cautious of the depth of focus decreasing rapidly. If the depth of focus is small, it is necessary to improve accuracy, reproducibility, and stability. Based on accuracy,

reproducibility, and stability, the automatic-focusing doubling system for doubling between the best image surface of a projection optical system and the regist layer sides on a wafer is controlled.

[0018]On the other hand, the composition to which a numerical aperture is made to increase is possible, without making the size of a view increase, when a projection optical system is taken into consideration from the standpoint of a design or manufacture. However, if a numerical aperture is substantially set as a big value, the diameter of a lens element will become large and, as a result, it will become difficult to form and process the optical material (for example, quartz and fluorite) of glassiness.

[0019]Subsequently, a dipping projection method may be used as a means for improving resolution, without making the numerical aperture of a projection optical system increase greatly. In this method, the space between a wafer and a projection optical system is filled up with the fluid. Please refer to United States patent (given to Tabarelli) 4,346,164th about this.

[0020]In this dipping projection method, the space between a wafer and the optical element which constitutes a projection optical system from projection one end (image surface side) is filled up with the fluid which has a refractive index near the refractive index of a photoresist layer. The number of effective apertures of the projection optical system seen from the wafer side increases by this, namely, resolution can be improved. It is expected that this dipping projection method can gain good image formation performance by choosing the fluid to be used.

[0021]The automatic-focusing doubling (AF) system is generally provided in the publicly known projection aligner now. This automatic-focusing doubling system can control the relative position of a wafer and a projection optical system correctly, and can make the surface of a wafer agree in the optimal image surface (conjugate side of reticle) of a projection optical system by it. This automatic-focusing doubling system is provided with the surface position detection sensor for detecting change of the position (Z direction position) of the height direction of a wafer surface by non-contact, and the Z direction regulatory mechanism for adjusting the interval between a projection optical system and a wafer based on this detected change.

[0022]In the projection aligner used now, the optical type sensor and the pneumatic micrometer type sensor are used as a surface position detection sensor. The electrode holder (and Z stage) for supporting a wafer is provided as a Z direction regulatory mechanism. The electrode holder (and Z stage) which supports a wafer moves perpendicularly in submicron accuracy.

[0023]Supposing such an automatic-focusing doubling system is provided in the aligner to which a dipping projection method is applied, since a wafer is held at a fluid, it is natural that cannot use a pneumatic micrometer type sensor but an optical sensor is used monopolistically.

In such a case, for example, an optical sensor for focusing which was indicated by United States patent (given to Suwa) 4,650,983rd is constituted. The beam for measurement which the beam for measurement (image formation beam of a slit image) was aslant projected on the projection view field on a wafer by it, and was reflected in the wafer surface lets the slit for light-receiving pass, and is received by the detector of a photoelectric method. The change of focal errors of the height of a wafer surface, i.e., the amount, is detected from change of the position of the reflected beam (reflective beam) which occurs to the slit for light-receiving.
[0024]The sensor for focusing of an oblique incidence light (light is entered aslant) type which was indicated by United States patent 4,650,983rd, If the usual projection optical system which has 10 thru/or 20-nm test working distance is directly attached to the projection aligner dipped in the fluid, the problem described below will arise. In such a case, it is necessary to set as a fluid the projection optical system along which the following projection beams and a reflective beam pass. That is, the projection beam is emitted from the object lens for projection of the sensor for focusing, and arrives at the projection view field of the projection optical system on a wafer. It is reflected by the wafer and the reflective beam reaches the object lens for light-receiving.
[0025]Therefore, the beam of the sensor for focusing progresses in a fluid covering a long distance. By it, if the temperature distribution of a fluid is not stable with high precision, since temperature is unequal, a projection beam and the received beam will be changed by change of a refractive index, and, as a result, the accuracy of focus detection (namely, detection of the position of the height direction of a wafer surface) will fall.
[0026]With a dipping projection method, in order to attain 0.15lambdam or the resolution not more than it, it is necessary to set the test working distance of a projection optical system as a value small enough to have mentioned above. Therefore, projection beam itself of the sensor for oblique incidence light (light is entered aslant) type focusing, One important question arises from the space between a projection optical system and a wafer how an automatic-focusing doubling system applicable to a dipping projection method should be constituted for this reason that becomes difficult [it / to project aslant towards the projection area on a wafer .
[0027]On the other hand, the aligner (exposure device) which has a projection optical system (henceforth "1X) single magnification type is used in the field which manufactures an LCD device (flat panel display) with the field which manufactures a semiconductor device. These days, one system (system) is proposed for this kind of aligner. A certain type of two or more 1X projection optical systems can be arranged, and it can scan now by a mask and a photosensitive plate receiving the system mutually, and moving to it in one. As for the test working distance of 1X projection optical system used, it is desirable that it is ideal extremely small. A single Dyson (single Dyson) type with which each 1X projection optical system was indicated by U.S. Pat. No. 4,391,494 (given to Hershel), Or it is the double Dyson (double

Dyson) type which was indicated by United States patent (given to Swanson etc.) 5,298,939th.

[0028]In the aligner which has a such Dyson (Dyson) type projection optical system, By fully decreasing test working distance (namely, interval between the exit surface of a prism mirror, and the image surface), the problem which can restrict the various aberration and distortion of an image which were projected to a small value, and is produced by aberration or distortion as a result is lost as a matter of fact. . Therefore, in this kind of aligner, a focus is detected by the sensor for focusing. The detection area (for example, the irradiation position of the projection beam in the oblique incidence light system which enters light aslant or the air discharge position in a pneumatic micrometer system) on a photosensitive substrate is usually set as the position which swerved from the effective projection view field field of the projection optical system. That is, it is set up by an off-axis method.

[0029]

[Problem(s) to be Solved by the Invention It is impossible to actually detect whether the field of the substrate exposed from a circuit pattern to projected light was correctly adjusted by a best focal position or state because of this reason.

[0030]In the device which draws a pattern to a substrate, Or in the device into which it is processed by using the spot of a laser beam or an electron beam (or manufacture), a substrate, the objective lens system (or electron lens system) for projecting a laser beam and an electron beam, and the test working distance between become very small. As a result, a possibility that it becomes impossible to attach the AF sensor which can detect the focal error of a processing position or can detect the focal error of the drawing position on the substrate face in the view of an objective lens optical system arises.

[0031]In such a case, the detection position of an AF sensor is placed by only the outside of the view of an objective lens system in order to detect a focal error. It becomes impossible therefore, to detect whether the focal error has actually occurred in the processing position or drawing position in a view of an objective lens system.

[0032]That it is the same as this can say the pattern drawn on reticle or a mask, and the detailed pattern formed in the wafer also about the device for inspecting optically by photo lithography. That is, it is because the objective lens system for an inspection is provided also in this kind of test equipment. The end of an objective lens system is because only predetermined test working distance separates from the surface of said specimen and is established toward the surface of the specimen (plate) inspected.

[0033]Therefore, if the objective lens system which is comparatively alike and has big magnification and high resolution is used, test working distance will become very small and, as a result, the same problem about the character of an AF sensor will arise.

[0034]

[Means for Solving the Problem In consideration of the above-mentioned problem of a pertinent art, the invention in this application, Even if a projection optical system which decreases test working distance as compared with the usual projection optical system is incorporated, a projection aligner (exposure device) and an exposure method which can perform control of focusing with high precision, and can do tilt control with high precision are provided.

[0035]The invention in this application relates to an aligner of a step-and-repeat type. The surface of a photosensitive substrate is exposed in an aligner of a step-and-repeat type by pattern image projected through a projection system or a scanning exposure device (scanning aligner). In a projection system or a scanning exposure device, it is a mask (.). Or reticle and a photosensitive substrate move relatively to a suitable system to detect while a pattern image is projected, move relatively to an image formation system, and these kinds of focal positions and tilts in an exposure device (aligner).

[0036]In an exposure device and an exposure method of the invention in this application, focusing control and tilt control are performed about a shot region in peripheral positions on a photosensitive substrate.

[0037]With a scanning exposure device and a scanning exposure method of the invention in this application, without setting a focus detection area as a projection view field of a projection optical system, about an exposure region of a photosensitive substrate, control of focusing can be performed with high precision, and tilt control can be done with high precision.

[0038]In a dipping type projection aligner and a dipping type scanning aligner which were designed in order to improve the depth of focus, a sensor and a focus detection method for focusing of the invention in this application are stabilized, and can detect an error in surface focusing or a tilt of a photosensitive substrate dipped in a fluid. A sensor and a focus detection method for focusing of the invention in this application are suitable for a manufacture (processing) device, a drawing device, or test equipment which has an objective lens optical system of small test working distance.

[0039]An image formation system (projection lens system) for the invention in this application to project a pattern image of a mask (reticle) on a substrate (wafer) through an image formation view, A scanning mechanism (a reticle stage or a wafer XY stage) for moving a mask and a substrate to a scanning direction to an image formation system, A substrate and an image formation system are received mutually, and it can apply to a scanning exposure device which has Z-drive system which doubles a focus of an image projected on a Z direction by driving. The invention in this application in order to position a substrate about an image formation system for projecting a pattern image of a mask on a substrate through a projection view field, and a pattern image projected, It is applicable to a projection aligner (namely, stepper) which has Z-drive system which doubles a focus of an image projected by receiving

mutually and driving a substrate and an image formation system to a Z direction with a movable stage mechanism which moves in the direction of X, and the direction of Y.

[0040]An exposure device, i.e., a scanning mechanism of an aligner, or a movable stage can be used as a mechanism for maintaining a mask or a substrate horizontally. Or an exposure device, i.e., a scanning mechanism of an aligner, or a movable stage is good also as a mechanism for maintaining a mask or a substrate at a certain fixed angle from the level surface. For example, it is good also considering a mask or a substrate as level or a vertical (every length) stage mechanism for making it move perpendicularly, maintaining a mask or a substrate with a vertical posture. In this case, a flat surface where a mask or a substrate moves has countered in the direction of X, and the direction of Y. A Z direction which lies at right angles to each of the direction of X and the direction of Y is also referred to (for example, a Z direction is in agreement in the direction of an optic axis of a projection optical system arranged in a transverse direction, or the direction of a chief ray).

[0041]According to the invention in this application, the 1st detection system, the 2nd detection system, and the 3rd detection system are provided in an aligner. The 1st detection system equips the 1st position with a detection area. The 1st position is provided in the outside of an image formation view of an image formation system, in a scanning direction (the direction of Y), from an image formation view of said image formation system, opens an interval and is established. The 1st detection system detects a position in a Z direction of the surface (upper surface) of a substrate. The 2nd detection system equips the 2nd position with a detection area. The 2nd position is provided in the outside of an image formation view of an image formation system, in direction (X) which intersects perpendicularly with a scanning direction (the direction of Y), from said 1st position, opens an interval and is established. The 2nd detection system detects a position in a Z direction of the surface of a substrate. The 3rd detection system equips the 3rd position with a detection area. The 3rd position is provided in the outside of an image formation view of an image formation system, in a direction (the direction of X) which intersects perpendicularly with a scanning direction (the direction of Y), from an image formation view of said image formation system, opens an interval and is established. In a scanning direction (the direction of Y), also from said 2nd position, the 3rd position opens an interval and is established again. The 3rd detection system detects a position in a Z direction of the surface of a substrate.

[0042]According to the invention in this application, to an aligner, a gap between 1st Z position and a target Z position which were detected by the 1st detection system is calculated further, By movement caused by a computer,; scanning mechanism, or a movable stage mechanism for memorizing temporarily 2nd Z position detected by the 2nd detection system when detected by the 1st detection system. When a field on a substrate corresponding to a detection area of the 1st detection system is positioned by image formation view of an image formation

system, a controller for controlling Z-drive system based on a calculated gap, 2nd memorized Z position, and 3rd Z position detected by the 3rd detection system; it is provided.
[0043]The invention in this application is applicable to a scanning exposure method. In this scanning exposure method, by projecting some mask patterns on a photosensitive substrate through a projection optical system, All the patterns of a mask (reticle) are transferred by photosensitive substrate (wafer) by moving a mask and a photosensitive substrate simultaneously to a projection view field of a projection optical system.
[0044]A method of the invention in this application is provided with the following.
A step for attaching a photosensitive substrate to an electrode holder which has the auxiliary plate part formed so that a photosensitive substrate might be surrounded in height substantially equal to surface height of a photosensitive substrate.
A step which reads a focal error of an exposure region on a photosensitive substrate a priori. Some patterns of a mask are projected on a field on said photosensitive substrate. While carrying out scanning movement of an electrode holder and the photosensitive substrate, before an exposure region arrives at a projection view field of a projection optical system, a focal error of an exposure region is read. A method of said invention in this application is provided with the following.
According to an exposure position focus detecting system which is distant from a projection view field of a projection optical system, and has been arranged in a direction (the direction of X) which intersects perpendicularly to the direction of scanning movement (the direction of Y) when an exposure region on a photosensitive substrate arrives at a projection view field. A step which detects a focal error of some surfaces of a photosensitive substrate or an auxiliary plate part.
A step which adjusts distance between a projection optical system and a photosensitive substrate based on a detected focal error so that a focal error of an exposure region on a photosensitive substrate may be amended in a projection view field of a projection optical system.

[0045]A manufacture (processing) device, an image formation device and a focus detection sensor suitable for test equipment, or a focus detection method, Instead of a projection optical system for an exposure device (aligner) mentioned above or an exposure method used, it is similarly attained by using an objective lens optical system for manufacture, drawing, image formation, or an inspection.
[0046]
[Embodiment of the Invention Drawing 1 shows the entire structure of the projection aligner in the 1st example of the invention in this application. The projection aligner of the 1st example is a lens scan type projection aligner. In the projection aligner, the circuit pattern on reticle lets a

reduction projection lens system pass, and is projected on a semiconductor wafer. Said reduction projection lens system is provided with the following.
The circular image vision field formed in telecentric system by the object side.
The circular image vision field formed in telecentric system by the image side.
On the other hand, reticle and a wafer move to a projection lens system, and are scanned (scan).
[0047]The illumination system shown in drawing 1 is provided with the following.
The ArF excimer laser light source for emitting the pulsed light which has the wavelength of 193 nm.
The beam expander for forming in predetermined shape the section of the pulsed light emitted from said light source.
An optical integrator like the fly eye lens for forming secondary light source images (two or more one-set point light sources) by receiving said pulsed light formed in predetermined shape.
The condensing lens system for condensing said pulsed light from said secondary light source images to the pulse illumination light which has uniform illuminance distribution, The reticle blind (lighting field diaphragm) for operating the pulse illumination light orthopedically in a rectangle long and slender in the direction which intersects perpendicularly to the scanning direction at the time of scanning exposure, The relay optical system for collaborating with the mirror 11 and the condensing lens system 12 which were shown in drawing 1, and carrying out image formation of the opening of the rectangle of a reticle blind to the reticle R.

[0048]The reticle R is supported by vacuum suction in the reticle stage 14. The reticle stage 14 is movable with constant speed in one dimension by big stroke during scanning exposure. It sees by drawing 1, and it shows around on the columnar structure object 13 of an aligner main part, and moves to a transverse direction, and the reticle stage 14 can be scanned now (scan). The reticle stage 14 is shown so that it can move in the direction which intersects perpendicularly to the flat surface of drawing 1 again.
[0049]The coordinates position of the reticle stage 14 in an XY plane and a delicate rotation gap are continuously measured by the laser-interferometer system (IFM) 17. The laser-interferometer system 17 ejects a laser beam to the moving mirror (a plane mirror or a corner mirror) 16 attached to a part of reticle stage 14. The laser-interferometer system 17 receives the laser beam reflected by the moving mirror 16 (that is, light is received). The reticle stage controller 20 controls the motor (it is (like a linear motor or a voice coil)) 15 which drives the reticle stage 14 based on XY-coordinates position measured by the laser-interferometer system 17. Scanning movement and stepping movement of the reticle stage 14 are controlled by it.

[0050]When a part of circuit pattern region of the reticle R is illuminated by the pulsed light formed in the rectangle emitted from the condensing lens system 12, It lets 1 4 (namely, 1 4) reduction-projection-lens system PL pass, and the image formation optical beam which comes out of the circuit pattern of the illuminated portion is projected on the photosensitive resist layer applied to the upper surface (namely, principal plane) of the wafer W, and carries out image formation. The optic axis AX of 1 4 reduction-projection-lens system PL is positioned so that it may elongate through the central point of a circular image vision field, and so that it may become the same axle to the optic axis of the illumination system 10, and the optic axis of the condensing lens system 12.

[0051]1 / 4 reduction-projection-lens system PL is provided with two or more lens elements. The lens element comprises quartz which has high transmissivity, and two different materials like fluorite, for example to the ultraviolet rays which have the wavelength of 193 nm. Fluorite is mainly used, in order to form the lens element which has Masachika (positive power). The air of the body tube to which the lens element of 1 / 4 reduction-projection-lens system PL was fixed is transposed to nitrogen gas. By this, the absorption of the pulse illumination light which has the wavelength of 193 nm by oxygen is avoidable. It is similarly transposed to nitrogen gas about the optical path applied to the condensing lens system 12 from the inside of the illumination system 10.

[0052]The wafer W is held at the wafer holder (zipper) WH. The wafer holder WH has drawn the rear face (rear flank) of the wafer by vacuum suction. The annular auxiliary plate part HRS is formed in the periphery of the wafer holder WH so that the circumference of the wafer W may be surrounded. The height of the annular surface of the auxiliary plate part HRS serves as substantially the upper surface of the wafer holder WH attached to the upper surface of the wafer holder WH with the same flat surface. When carrying out scanning exposure of the shot region in the peripheral positions on the wafer W so that the following may explain in detail, If the detecting point (namely, detecting point) of the sensor for focusing is positioned by the outside of the outline edge of the wafer W, the annular auxiliary plate part HRS will be used as an alternative focus detection side.

[0053]The annular auxiliary plate part HRS functions as a flat reference plate (reference plate) for proofreading system offset of the sensor for focusing as indicated by above-mentioned (given to Suwa) United States patent 4,650,983rd. A needless to say and special reference plate is provided independently, and it may be made to proofread the sensor for focusing.

[0054]The wafer holder WH is attached to the ZL stage 30. The ZL stage 30 can carry out translation motion to a Z direction in accordance with the optic axis AX of 1 4 reduction-projection-lens system PL. The ZL stage 30 is movable also in the direction which intersects perpendicularly to the optic axis AX, while carrying out tilt motion to the XY plane. The ZL stage 30 is attached to XY stage 34 via the three Z-actuators 32A, 32B, and 32C. XY stage 34

is movable to two dimensions in the direction of X, and the direction of Y on a base. Each of the Z-actuators 32A, 32B, and 32C serves as a piezo elastic element, a voice coil motor or a DC motor, and combination of the lift cam mechanism, for example.

[0055]Supposing each of the Z-actuators 32A, 32B, and 32C (namely, Z-drive motor) drives only the same quantity as a Z direction, while between XY stages 34 is maintained in parallel, translation motion of the ZL stage 30 will be carried out to a Z direction (namely, direction which performs focusing). Supposing each of the Z-actuators 32A, 32B, and 32C drives only quantity which is different in a Z direction, the amount of tilts (inclination) and tilting directions of the ZL stage 30 will be adjusted by it.

[0056]Two-dimensional movement of XY stage 34 is caused by some drive motors 36. The drive motor 36 is a linear motor etc. which can generate driving force by the DC motor (namely, direct current motor) made to rotate a feed screw or a noncontact state, for example. The drive motor 36 is controlled by the wafer stage controller 35. The measurement-coordinates position from the laser interferometer (IFM) 33 is supplied to the wafer stage controller 35 so that change of the position in the direction of X and the direction of Y of a reflector of the moving mirror 31 can be measured.

[0057]For example, entire structure of XY stage 34 which uses a linear motor as the drive motor 36 can be made into what is indicated by Provisional Publication No. 61-209831st (Tateishi electrical-and-electric-equipment incorporated company) exhibited on September 18, 1986.

[0058]About this example, the work distance (test working distance) of 1 4 reduction-projection-lens system PL, It is very small, therefore the projection beam of the sensor for focusing of the type of oblique incidence light passes along the space between the surface of the optical element of 1 / 4 reduction-projection-lens system PL nearest to the image surface, and the upper surface of the wafer W, and it is thought that it cannot lead on the surface of a wafer. The three off-axis type (the outside of the projection view field of 1 4 reduction-projection-lens system PL is equipped with the focus detection point) focus detecting systems GDL, GDC, and GDR are arranged in therefore this example on the outskirts of a lower part end of the barrel (body tube) of 1 / 4 reduction-projection-lens system PL.

[0059]The focus detecting systems GDL and GDR are set up among these focus detecting systems have the focus detection point (focus detection point) positioned by the front side of a projection view field, and the backside to the direction of scanning movement of the wafer W at the time of scanning exposure. When one shot region of the wafer W is scanned and exposed, one side of the focus detecting systems GDL and GDR selected according to the direction of scanning movement (a plus direction or the minus direction) operates, A rectangular projection image has the change in the height position of the surface of a shot region predicted, before being exposed by the wafer.

[0060]Therefore, the focus detecting systems GDL and GDR function as the prediction sensor of the focus detecting system indicated by United States patent (given to SAKAKIBARA etc.) 5,448,332nd in a similar manner, for example. However, in this example, different sequences from the sequence of the 5,448,332nd focus (or tilt adjustment) of an United States patent are used, therefore the special focus detecting system is added to the focus detecting systems GDL and GDR. This structure is explained in detail by the following.

[0061]Focus detecting system GDC shown in drawing 1 equips the non-scanning direction which intersects perpendicularly to the scanning direction of the projection view field of 1 4 reduction-projection-lens system PL with the detecting point (detecting point) arranged by the off-axis method, when it sees on the surface (namely, XY plane) of the wafer W. However, in addition to the detecting point by the side of front [of 1 / 4 reduction-projection-lens system PL , focus detecting system GDC equips the backside of 1 4 reduction-projection-lens system PL with other detecting points, seeing by drawing 1.

[0062]The focus detection method according to the invention in this application has the feature in the point that off-axis focus detecting system GDC and one side of the prediction focus detecting systems GDL and GDR collaborate mutually, and operate. Detailed explanation of these focus detecting systems is mentioned later.

[0063]The information about some height positions of the wafer surface detected by each of the focus detecting systems GDL, GDR, and GDC mentioned above, including for example, the error signal showing the amount of gaps from the best focal position, etc., is inputted into the automatic-focusing doubling (AF) control unit 38. Based on the detection information supplied from the focus detecting systems GDL, GDR, and GDC, the AF control unit 38, The optimal quantity that drives each of the Z-drive motors 32A, 32B, and 32C as a Z-actuator is determined, the Z-drive motors 32A, 32B, and 32C are driven, focusing is performed to the field of the wafer W in which a projection image actually carries out image formation, and tilt adjustment is performed.

[0064]For this control, each of the focus detecting systems GDL and GDR serves as a sensor for multipoint (multipoint) focusing. This sensor has a detecting point in two or more positions (for example, at least two positions) in the rectangle projection area on the wafer W formed of 1 / 4 reduction-projection-lens system PL. Focusing has come for the AF control unit 38 to be, able to carry out tilt adjustment of the wafer W in a non-scanning direction (the direction of X), of course at least.

[0065]By moving in the direction of Y with constant speed in XY stage 34, the aligner shown in drawing 1 is constituted so that scanning exposure may be performed. The relation between scanning movement of the reticle R and the wafer W between scanning exposure and stepping movement of the reticle R and the wafer W is explained with reference to drawing 2.

[0066]If drawing 2 is referred to, the front group lens system LGa and the back group lens

system LGb express 1 4 reduction-projection-lens system PL shown in drawing 1. The exit pupil Ep exists between the front group lens system LGa and the back group lens system LGb. Circuit pattern region Pa is formed in the frame (frame) demarcated by cover belt SB on the reticle R shown in drawing 2. Circuit pattern region Pa has larger diagonal line length than the diameter of the circular image vision field formed on the object 1 4 reduction-projection-lens system PL side.

[0067]By a scanning method, the image of circuit pattern region Pa of the reticle R is exposed by the corresponding shot region SAa on the wafer W. This scanning method is held by moving the wafer W to the plus direction which met the Y-axis with the constant speed Vw, while moving the reticle R in the minus direction which met the Y-axis at the fixed speed Vr, for example. At this time, in circuit pattern region Pa of the reticle R, the shape of the pulse illumination light IA for illuminating the reticle R is set as a parallel strip or a rectangle long and slender in the direction of X, as shown in drawing 2. The both ends of the shape of the pulse illumination light IA which has countered mutually in the direction of X are positioned by cover belt SB.

[0068]The partial pattern contained in the rectangle region of circuit pattern region Pa of the reticle R irradiated by the pulse illumination light IA, By 1 4 reduction-projection-lens system PL (the front group lens system LGa and the back group lens system LGb), image formation is carried out to the correspondence position in the shot region SAa of the wafer W as image SI. When relative scanning between circuit pattern region Pa on the reticle R and the shot region SAa on the wafer W is completed, only a fixed distance carries out 1 step moving of the wafer W in the direction of Y, for example.The starting position of scanning is set up to the shot region SAb contiguous to the shot region SAa by it. The lighting by the pulse illumination light IA has stopped during this stepping operation.

[0069]Next, in order to expose the circuit pattern image of circuit pattern region Pa of the reticle R to the shot region SAb on the wafer W by a scanning method, the reticle R moves to the plus direction of a Y-axis with the constant speed Vr to the pulse illumination light IA. And the wafer W moves in the minus direction of a Y-axis with the constant speed Vw to projected image SI simultaneously. Velocity ratio Vw Vr is set as the reduction ratios 1 4 of 1 4 reduction-projection-lens system PL. According to the above-mentioned schedule, the image of circuit pattern region Pa of the reticle R is exposed by two or more shot regions on the wafer W.

[0070]The projection aligners shown in drawing 1 and drawing 2 are the following methods, and can be used as an aligner of a step and repeat system. Namely, if the diagonal line length of circuit pattern region Pa on the reticle R is smaller than the diameter of the circuit image vision field of 1 4 reduction-projection-lens system PL, The shape and size of an opening of a reticle blind in the illumination system 10 change, and the shape of the pulse illumination light

IA is in agreement with circuit pattern region Pa by it. In such a case, the reticle stage 14 and XY stage 34 are maintained by the state where it was relatively stood still while exposing each of the shot region on the wafer W.

[0071]However, supposing the wafer W moves slightly between exposure, slight movement of the wafer W can be measured by the laser-interferometer system 33. The small error to which the position of the wafer W to 1 4 reduction-projection-lens system PL is equivalent can be negated by moving slightly under control in the reticle stage 14, and as a result carrying out flattery amendment by the reticle R side. For example, the system for such flattery amendment is indicated by JP,6-204115,A and JP,7-220998,A. The art indicated by these publications before examination can be used if needed.

[0072]If the shape and size of an opening of a reticle blind change, the pulse illumination light IA which reaches a reticle blind from a light source can be collected within limits adjusted to the adjusted opening by establishing a zoom lens system according to change of the shape of an opening, or size.

[0073]The field of projected image SI as clearly shown in drawing 2, From being set as strip shape or rectangular shape long and slender in the direction of X, tilt adjustment between scanning exposure can be performed, only by meeting the rolling directions to the direction which rotates a Y-axis as a center, i.e., the scanning exposure direction in this example. Supposing the width in the scanning direction of the projected image SI field is large needless to say to such an extent that it needs to take into consideration the influence of the flatness of a wafer surface to a scanning direction, tilt adjustment in a pitching direction will be performed between scanning exposure. This operation is explained more to details about other examples of the invention in this application.

[0074]The focus detecting systems GDL, GDR, and GDC shown in drawing 1 are arranged, for example, as illustrated by drawing 3. Drawing 3 is the perspective view showing arrangement of the detecting point of the focus detecting system on the flat surface in which circular image vision field CP is formed by the image side of 1 4 reduction-projection-lens system PL. Drawing 3 shows only arrangement of the focus detecting systems GDL and GDC. Focus detecting system GDR is omitted. It is because focus detecting system GDR is the same structure as the focus detecting system GDL.

[0075]If drawing 3 is referred to, focus detecting system GDC is provided with the two detectors GDC1 and GDC2. The detectors GDC1 and GDC2 are set up so that the detecting points (detection area) FC1 and FC2 may be positioned on the extension wire LLc elongated from the axis of image SI with which the rectangle was projected by the strip. Image SI on which the rectangle was projected by the strip is circular image vision field CP of 1 4 reduction-projection-lens system PL, and is elongated to the diametral direction (the direction of X). These detectors GDC1 and GDC2 detect the amount of position errors of the Z direction

to the height position on top and the best focal plane position of the wafer W (or auxiliary plate part HRS).

[0076]On the other hand, the focus detecting system GDL is provided with five detector GDA1, GDA2, GDB1, GDB2, and GDB3 in this example. Detector GDA1, GDA2, GDB1, GDB2, and GDB3 are provided with detecting point (detection area) FA1, FA2, FB1, FB2, and FB3, respectively. Detecting point FA1, FA2, FB1, FB2, and FB3 are positioned by the straight line LLa parallel to the extension wire LLc. These five each, detector GDA1, GDA2, GDB1, GDB2, and GDB3, detects the amount of position errors of the Z direction to the height position and the best focal plane position of a point in the upper surface of the wafer W (or auxiliary plate part HRS) independently.

[0077]The extension wire LLc and the straight line LLa set constant distance to a scanning direction (the direction of Y) mutually, and are set as it. Detecting point FAof detector GDA1 1 and detecting point FCof detector GDC11 are substantially set as the same coordinates position in the direction of X. On the other hand, detecting point FAof detector GDA2 2 and detecting point FCof detector GDC22 are substantially set as the same coordinates position in the direction of X.

[0078]Three detector GDB1, GDB2 and detecting point FB1 of GDB3, FB2, and FB3 are arranged so that the field of image SI where the strip or the rectangle was projected may be covered in the direction of X. That is, detecting point FB2 is arranged at the X coordinate position corresponding to the center (point along which the optic axis AX passes) in the direction of X of the field of projected image SI. On the other hand, the detecting points FB1 and FB3 are arranged at the X coordinate position corresponding to the position near in the direction of X of projected image SI both ends. Therefore, three detecting point FB1, FB2, and FB3 are used, and the focal error in the surface part of the wafer W corresponding to the projected image SI field can be predicted now.

[0079]Focus detecting system GDR which is not illustrated by drawing 3 is also equipped with three prediction detector GDE1, GDE2 and GDE3, and other two detectors GDD1 and GDD2. The detectors GDD1 and GDD2 are arranged at the both sides of the direction of X of prediction detector GDE1, GDE2, and GDE3. In this example in order to explain simply, Two or more flat surfaces accepted by 12 detector GDA1, GDA2;GDB1, GDB2, DB3;GDC1, GDC2;GDD1, GDD2;GDE1, GDE2, and GDE3 as two or more best focal positions are assumed to be what is adjusted in one XY plane. That is, there is no offset on a system among 12 detectors. The surface height position of the wafer W detected by 12 detecting point FA1, FA2;FB1, FB2, FB3;FC1, FC2;FD1, FD2;FE1, FE2, and FE3 is assumed to receive mutually and to approach mostly as a position from which the detected focal error becomes zero.

[0080]If the end of 1 4 reduction-projection-lens system PL is not dipped in a fluid, a photo sensor, an air micrometer type sensor, an electric capacity type gap (gap) sensor, etc. can be

used as 12 focus detectors mentioned above. However, if the projection system of the dipping type is formed, of course, an air micrometer type sensor cannot be used.

[0081]Drawing 4 is a block diagram of an example of the AF control unit 38 for processing the detecting signal (error signal) from the focus detecting systems GDL, GDR, and GDC shown in drawing 1 and drawing 3. As shown in drawing 4 The group of the detecting signal from five detector GDA1 of the prediction focus detecting system GDL, GDA2, GDB1, GDB2, and GDB3, One group of the groups of the detecting signal from five detector GDD1 of focus detecting system GDR, GDD2, GDE1, GDE2, and GDE3 is chosen by the switch circuit 50, and is supplied to a subsequent processing circuit.

[0082]The switch circuit 50 answers switching signal SS1 supplied from the position supervisory circuit (position monitoring circuit) 52 (the result of distinction of a direction is expressed), and chooses the signal from one side of the focus detecting systems GDL and GDR. The position supervisory circuit 52 distinguishes one move direction of the scanning move direction of the wafer stage 34 from the move direction of another side based on the stage control information from the wafer stage controller 35. The position supervisory circuit 52 is supervising change of the position which the wafer W moved from the prediction position to the exposure position. In the state by which it was shown in drawing 4, the switch circuit 50 has chosen five detecting signals from the focus detecting system GDL.

[0083]The detecting signal from prediction detector GDB1 about an exposure region (projected image SI), GDB2, and GDB3 is supplied to the 1st computer 54 for calculating the amount of focal errors, and the amount of tilt errors. The 1st computer 54 supplies amount of focal errors deltaZf of the surface area of the wafer W read a priori by three detecting point FB1, FB2, and FB3, and error data DT1 about amount of tilt errors deltaTx (delicate inclination centering on a Y-axis) and DT2 to the 2nd calculation and store circuit 56.

[0084]On the other hand, the detectors GDA1 and GDA2 supply information ZA1 and information ZA2 to the 2nd calculation and store circuit 56. Information ZA1 expresses the height position (namely, focal gap) of the surface in detecting point FA1. Information ZA2 expresses the height position (namely, focal gap) of the surface in detecting point FA2. Detection of information ZA1 and the information ZA is performed simultaneously with detection of the wafer surface by three detector GDB1, GDB2, and GDB3.

[0085]Based on the error data DT1 and DT2, the information ZA1 and ZA2, and the relative position relation between detectors, the 2nd calculation and store circuit 56, The desired values delta Z1 and delta Z2 of the height position of the wafer W which should be detected with the detecting points FC1 and FC2 of the detectors GDC1 and GDC2 set as the projection exposure position about the direction (scanning direction) of Y are calculated. The 2nd calculation and store circuit 56 memorize the calculated desired values delta Z1 and delta Z2 temporarily.

[0086]The meaning of the desired values delta Z1 and delta Z2 is as follows. Namely, the wafer W (.) read a priori with the prediction detecting points FA1 and FA2 Or when the surface part of the annular auxiliary plate part HRS reaches the detecting points FC1 and FC2 in a corresponding exposure position, If information ZC1 and information ZC2 which were detected by the detectors GDC1 and GDC2 are equal to the desired values delta Z1 and delta Z2 respectively, amount of focal errors deltaZf and amount of tilt errors deltaTx which are determined by prediction will become zero in an exposure position.

[0087]Just before the field about the direction of Y on the predicted wafer arrives at the exposure position where projection image SI is exposed, the 2nd calculation and store circuit 56 output the memorized desired values delta Z1 and delta Z2 to the 3rd calculation and drive circuit 58.

[0088]Therefore, synchronizing with signal SS2 outputted from the position supervisory circuit 52, the 2nd calculation and store circuit 56 output the signal showing the desired values delta Z1 and delta Z2 memorized temporarily to the 3rd calculation and drive circuit 58. After only the time determined look like the distance between the straight line LLa and the extension wire LLc in the direction of Y and the movement speed of the wafer W said signal showing the desired values delta Z1 and delta Z2 is delayed, it is outputted to the 3rd calculation and drive circuit 58.

[0089]If signal SS2 is outputted whenever the wafer W moves and only the distance corresponding to the width of projection image SI in a scanning direction is scanned, The distance in the direction of Y between the straight line LLa and the extension wire LLc which were shown in drawing 3. The desired values delta Z1 and delta Z2 of the fixed group (for example, 5 sets) of a number corresponding to the number obtained by doing division of (for example, about 40 mm) by the width (about 8 mm) of projection image SI are memorized in the 2nd calculation and store circuit 56. Therefore, the 2nd calculation and store circuit 56 function as a memory which memorizes the desired values delta Z1 and delta Z2 by the first-in first-out (FIFO) method.

[0090]The 3rd calculation and drive circuit 58 answer signal SS3 from the position supervisory circuit 52, and read the detection information ZC1 and ZC2 about the height position of the surface of the wafer W (or annular auxiliary plate part HRS) detected by the detectors GDC1 and GDC2. Immediately after that, the field on the wafer W detected in the prediction position reaches in an exposure position (position of projected image SI).

[0091]Simultaneously, the 3rd calculation and drive circuit 58 read the data of the desired values (it corresponds to an exposure position) delta Z1 and delta Z2 outputted from the 2nd calculation and store circuit 56. And the 3rd calculation and drive circuit 58 determine the drive quantity (quantity of centering control, and quantity of speed regulation) corresponding to the Z-drive motors 32A, 32B, and 32C shown in drawing 1 by calculation based on the detection

information ZC1 and ZC2 and the desired values delta Z1 and delta Z2. Subsequently, the 3rd calculation and drive circuit 58 output the data of the determined drive quantity to the Z-drive motors 32A, 32B, and 32C.

[0092]Almost all the components of drawing 4 are materialized by the microcontroller and microprocessor which execute the suitable program which can write by a person skilled in the art from a viewpoint of drawing 4 and which were programmed.

[0093]Drawing 5 is a top view explaining the function of the annular auxiliary plate part HRS formed in the periphery of a wafer holder as shown in drawing 1. In this example, all the detecting points of a focus detecting system, From being positioned by the outside of projection view field CP of 1 4 reduction-projection-lens system PL which was mentioned above. When carrying out scanning exposure of the shot region of shoes to be arranged among two or more shot regions SAn on the wafer W at the periphery of this wafer W, some focus detection points may be placed by the surrounding outside of the wafer W.

[0094]For example, when scanning exposure of shot region SA1 of the wafer W positioned on the wafer holder WH using the notch PURIARAIMENTO notch (aligned a priori) NT of the circumference is carried out as shown in drawing 5, Focus detection point FA1 (or FD1) in the end of the prediction focus detecting system GDL (or GDR) and detecting point FC1 of focus detecting system GDC of an exposure position are placed by the outside of the wafer W. In this case, it is usually difficult to perform focusing and tilt adjustment.

[0095]The main functions of the annular auxiliary plate part HRS are making usual focusing and tilt motion possible in such a case. Detecting point FA1 (or FD1) and detecting point FC1 which were placed by the outside of the wafer W are set up so that it may be positioned on the surface of the annular auxiliary plate part HRS, as shown in drawing 5. Therefore, as for the height of the annular surface of the auxiliary plate part HRS, it is desirable that it is substantially equal to the height of the surface of the wafer W.

[0096]When it explains more concretely, the surface of the wafer W and the surface of the annular auxiliary plate part HRS are in the detection range corresponding to detecting point FA1 (FA2), FC1 (FC2), and FD1 (FD2), and it receives mutually and is on the same flat surface. In the detection range, the linearity of the request of the focus detector corresponding to a detecting point is secured. the grade as the reflectance of a standard wafer (silicon) that the reflectance of the auxiliary plate part HRS is the same since it is used instead of the surface of the annular auxiliary plate part HRS being the surface of the wafer W -- or it has the same value. For example, as the annular auxiliary plate part HRS, the surface by which mirror finish was carried out is preferred.

[0097](On the wafer holder WH) If the wafer W moves in the direction of the arrow shown in drawing 5 and is scanned, detecting point FA1 of the focus detecting system GDL, FA2;FB1, FB2, and FB3 will be chosen as a prediction sensor about shot region SA1. In this case, the

extension wire LLc corresponding to a center for the ability to set in the direction of Y of projection image SI, Set to DLa distance between the straight lines LLa by which the detecting point of the focus detecting system GDL is arranged, and if distance between the extension wire LLc and the straight line LLb by which the detecting point of focus detecting system GDR of another side is arranged is set to DLb, In this example, DLa and DLb are set up so that DLa may become almost equal to DLb. Time delay deltat concerning the focal prediction position on the wafer W arriving at an exposure position is deltat DLa Vw (second) from the speed Vw of the wafer W at the time of scanning exposure. Therefore, in the 2nd the calculation and store circuit 56 that were shown in drawing 4, the time for memorizing temporarily the desired values delta Z1 and delta Z2 is equal substantially with time lag (time lag) deltat.

[0098]However, it may be made to choose the distance DLa and the distance DLb according to the restrictions related to the structure of an aligner, so that DLa may not become equal to DLb. Needless to say, in such a case, the desired value deltaZ1 and the time delay of supply of deltaZ2 are set as different length about use of the prediction focus detecting system GDL, and use of prediction focus detecting system GDR.

[0099]Focusing of the 1st example and the operation of tilt motion which were constituted as mentioned above are explained with reference to drawing 6 A thru/or drawing 6 D. Drawing 6 A shows in graph the state of the upper side surface of the annular auxiliary plate part HRS and the state of the upper side surface of the wafer W which were detected by the prediction focus detecting system GDL at a certain moment it is carrying out scanning exposure of circumference shot region SA1 of the wafer W as shown in drawing 5] of a between.

[0100]In drawing 6 A thru/or drawing 6 D, horizontal line BFP shows the optimal focal plane of 1 / 4 reduction-projection-lens system PL. Detector GDB1 which detects the position in the Z direction of a wafer surface by detecting point FB1 in shot region SA1 outputs the detecting signal with which deltaZB1 is expressed as an amount of Z position errors of the wafer surface over flat-surface BFP (an out-of-focus quantity, i.e., a defocusing amount). Similarly, the detectors GDB2 and GDB3 which detect the error of the position in the Z direction of a wafer surface with the detecting points FB2 and FB3 output the detecting signal showing the errors delta ZB2 and delta ZB3. If a wafer surface is below optimal focal plane BFP, each of these Z position error has a negative value. If a wafer surface is above optimal focal plane BFP, each of Z position error has a positive value.

[0101]The value of these errors delta ZB1, delta ZB2, and delta ZB3 is inputted into the 1st the calculation and store circuit 54 that were shown in drawing 4. The 1st calculation and store circuit 54 determine the parameter of the expression showing the approximate surface APP (in practice approximation straight lines) shown in drawing 6 B of the predicted whole portion in shot region SA1 by the least-squares method etc. based on these error values. The parameters determined by it are amount of focal errors deltaZf of the approximate surface

APP, and amount of tilt errors deltaTx, as shown in drawing 6 B. Thus, the value of calculated amount of focal errors deltaZf and amount of tilt errors deltaTx is outputted to the 2nd calculation and store circuit 56 as data DT1 and data DT2. In this example, amount of focal errors deltaZf is calculated as a substantial error in the central point in the direction of X of shot region SA1 (it corresponds to detecting point FB2).

[0102]As detector GDB1, GDB2, and GDB3 are mentioned above, when Z position error is detected, the detectors GDA1 and GDA2, The Z position errors delta ZA1 and delta ZA2 of a wafer surface or the surface of the annular auxiliary plate part HRS over the optimal focal plane in the detecting points FA1 and FA2 are detected simultaneously. These errors delta ZA1 and delta ZA2 are memorized temporarily in the 2nd calculation and store circuit 56.

[0103]Supposing the approximate surface APP as shown in drawing 6 B immediately after this detection and memory is amended so that it may be in agreement with optimal focal plane BFP as shown in drawing 6 C, Namely, supposing the wafer holder WH is adjusted in a Z direction and the direction of tilt motion so that it may be set to amount of tilt errors deltaTx 0 so that it may be set to amount of focal errors deltaZf 0 and, The 2nd calculation and store circuit 56 The data DT1 and DT2 (error amounts delta Zf and delta Tx), The Z position errors delta ZA1 and delta ZA2 actually measured with the detecting points FA1 and FA2, Based on distance DS in the direction of X between each of the central point of a shot region, and the detecting points FA1 and FA2, Z position target value deltaZ1 which should be detected by detecting point FA1, and Z position target value deltaZ2 which should be detected by detecting point FA2 are calculated. Calculated Z position target values delta Z1 and delta Z2 are temporarily memorized in the 2nd calculation and store circuit 56 until the predicted field on the wafer W arrives at the field of projection image SI (exposure position).

[0104]When the predicted field on the wafer W arrives at an exposure position, in order that the 3rd the calculation and drive circuit 58 that were shown in drawing 4 may detect Z position error in the detecting points FC1 and FC2, the detecting signal from the detectors GDC1 and GDC2 is read. For example, if the predicted field on the wafer W is in the state where it was shown in drawing 6 D just before arriving at an exposure position, detector GDC1 will output detecting-signal ZC1 showing Z position error of detecting point FC1. On the other hand, detector GDC2 outputs detecting-signal ZC2 showing Z position error of detecting point FC2.

[0105]Subsequently, the value of the detecting signals ZC1 and ZC2 which are supplied from the detectors GDC1 and GDC2 in the 3rd calculation and drive circuit 58, So that it may become equal to Z position target values delta Z1 and delta Z2 which are delayed and are supplied from the 2nd calculation and store circuit 56, respectively, In a Z direction, the three Z-actuators 32A and 32B required a tilt and or in order to carry out translation motion, and the drive quantity for 32C are calculated for the wafer holder WH. The 3rd calculation and drive circuit 58 supply the signal corresponding to said calculated drive quantity to the Z-actuators

32A, 32B, and 32C.

[0106]Shot region SA1 of the upper surface of the wafer W is an exposure position, and it is correctly adjusted by it so that it may be in agreement with optimal focal plane BFP. As a result, projection image SI of the pattern of the reticle R which should be maintained by the optimal image formation state is exposed in the scanning mode of a shot region.

[0107]Between this operation in the 1st example, each detector in the prediction focus detecting system GDL, and each detector in exposure position focus detecting system GDC, the flume which does not have a focal error when the surface of the wafer W or the surface of the annular auxiliary plate part HRS is in agreement with optimal focal plane BFP -- things are shown -- it is set up carry out a detecting-signal output (proofreading). However, it is difficult to set a detector as such a state strictly. The detection offset between the detectors GDA1 and GDA2 (GDD1 and GDD2) in the prediction focus detecting system GDL (GDR) and the exposure position focus detectors GDC1 and GDC2 makes the pattern image formed in the wafer W for exposure, as for a focus, cause a gap uniformly especially.

[0108]Therefore, the height position in the Z direction from which detector GDC1 detects the focal error of zero, Detector GDA1 (GDD1) the offset value between the height positions in the Z direction which detects the focal error of zero, It may be made to measure and memorize by performing focus detection simultaneously with these detectors on the surface of the reflective glass plate (namely, reference plate) provided in the wafer holder WH where display flatness is very high. This surface can be made into other structures of a different body in the structure HRS or the structure HRS. As a result, when the Z-actuators 32A, 32B, and 32C drive based on Z position error detected by the exposure position focus detectors GDC1 and GDC2, the memorized offset value can amend.

[0109]The structure of the focus concerning the 2nd example of the invention in this application and a tilt sensor is explained with reference to drawing 7 and drawing 8 below. About the 2nd example, projection image SI contained in the circular view of 1 4 reduction-projection-lens system PL was comparatively alike in the direction (scanning direction) of Y, is provided with the big maximum width, and by it. The situation where it should be necessary to take the influence of pitching (pitch) of the tilt to the direction of Y of the surface of the wafer W, i.e., influence, into consideration is assumed.

[0110]Exposure position focus detector GDC1 (not shown) is provided, and exposure position focus detector GDC1 is provided with two detecting point FC1a and FC1b as shown in drawing 7. Detecting point FC1a and FC1b are symmetrically arranged considering the extension wire LLc as a center in the direction of Y above projection image SI. And another exposure position focus detector GDC2 (not shown) is provided. Exposure position focus detector GDC2 is provided with two detecting point FC2a and FC2bs. Detecting point FC2a and FC2b are symmetrically arranged considering the extension wire LLc as a center in the direction of Y

below projection image SI. Prediction focus detector GDA1 and prediction focus detector GDA2 (not shown) are provided. Prediction focus detector GDA1 is provided with two detecting point FA1a and FA1b. Detecting point FA1a and FA1b are symmetrically arranged considering the straight line LLa as a center in the direction of Y. Prediction focus detector GDA2 is provided with two detecting point FA2a and FA2bs.Detecting point FA2a and FA2b are symmetrically arranged considering the straight line LLa as a center in the direction of Y. Similarly, prediction focus detector GDD1 (not shown) and prediction focus detector GDD2 (not shown) are provided. Prediction focus detector GDD1 is provided with two detecting point FD1a and FD1b. Detecting point FD1a and FD1b are symmetrically arranged considering the straight line LLb as a center in the direction of Y. Prediction focus detector GDD2 is provided with two detecting point FD2a and FD2bs. Detecting point FD2a and FD2b are symmetrically arranged considering the straight line LLb as a center in the direction of Y.

[0111]The prediction focus detector (n= 1, 2, 3) (not shown) GDBn and the prediction focus detector (n= 1, 2, 3) (not shown) GDEn are formed again. The prediction focus detector GDBn is provided with two or more pairs of detecting point FB1a and FB1 b;FB 2a, FB2b;FB3a, and FB3b. The prediction focus detector GDEn is provided with two or more pairs of detecting point FE1a and FE1 b;FE 2a, FE2b;FE3a, and FE3b. The detecting point of each set separates from each other in the direction of Y, opens a fixed interval and is formed.

[0112]The focus detecting system shown in drawing 7 is the same method as the 1st example mentioned above, In the detecting point of the off-axis detectors GDC1 and GDC2, an adjusting amount (namely, desired values delta Z1 and delta Z2) required in order to amend the shape of surface type of each predicted shot region (namely, error amounts delta Zf and delta Tx) is reproduced. A focus in by it the Z direction of an exposure region and the tilt adjustment in the direction (rolling directions, i.e., the rolling direction) of X are possible.

[0113]In this example, the prediction focus detecting system GDL (GDR) and exposure position focus detecting system GDC, From having two or more pairs of detecting points (FAna, FAnb;FBna, FBnb;FCna, FCnb;FDna, FDnb;FEna, and FEnb) with which only constant distance opened the interval and was established in the direction of Y. Amount of tilt errors deltaTy of the predicted shot region in a pitching direction, Are detectable from the difference between Z position errors in the detecting point (... na, ... nb) which forms two or more pairs in the direction of Y, An adjusting amount (namely, desired values delta ZA1 and delta ZA2) required to amend the shape of surface type of the shot region containing amount of tilt errors deltaTy is renewable with the detecting point (FCna and FCnb) of the off-axis detectors GDC1 and GDC2.

[0114]Detector GDB1, GDB2, and GDB3 for detecting a focal position by detecting point FB1 shown in drawing 3, FB2, and FB3 are arranged as a system which carried out mutually-independent by fixing to the lower part of 1 4 reduction-projection-lens system PL. However,

these three detector GDB1, GDB2, and GDB3 can let a common objective lens system pass, and they can constitute it so that a focal position may be detected by detecting point FB1, FB2, and FB3. at least The same thing can be said also about the group of three detector GDE1 for detecting a focal position by detecting point FB1 shown in drawing 5, FB2, and FB3, GDE2, and GDE3.

[0115]About the group of six detectors who detects a focal position by six detecting point FBna (s) and FBnb (n 1, 2, 3) which were shown in drawing 7, Or an objective lens system common for the same purpose may be used about other groups of six detectors who detect a focal position by six detecting point FEna(s) and FEnb (n 1, 2, 3). Therefore, two or more detecting points explain briefly the composition which uses the common objective lens system for detectors which detects a focal position with reference to drawing 8.

[0116]Drawing 8 is an abbreviated side view position-related [between the projection lens and detector which were seen in the direction of Y by drawing 7]. The detector supports six detecting point FBna(s) and FBnb (n 1, 2, 3) which were shown in drawing 7, four detecting point FA1a and FA1b, FA2a, and FA2b. Therefore, the scanning direction of the wafer W in drawing 8 aims to intersect perpendicularly to the flat surface of the drawing 8 concerned. Five detecting point FA1a arranged in the direction of X at the single tier in the position of the leftmost of drawing 7, FBna (n 1, 2, 3), and FA2a are represented and shown in drawing 8. Detecting point FA1b, FBnb (n 1, 2, 3), and FA2b of another sequence adjoin five (setting in the direction which intersects perpendicularly to the space of drawing 8) detecting point FA1a and FBna(s) (n 1, 2, 3), and FA2a. In this example, the focal position in these ten detecting points is detected by an objective lens system.

[0117]The illumination light ILF from the illumination-light study system 80A containing light sources (for example, a light emitting diode, a laser diode, a halogen lamp, etc.) is emitted through each of ten small slits formed in the multi-slits plate 81A as shown in drawing 8. Said light source can emit light of the wavelength area which the regist layer on the wafer W does not expose. Ten small slits are arranged corresponding to ten detecting point FBna, FBnb (n 1, 2, 3), FA1a, FA1b and FA2a which were set as the wafer W, and FA2b. The transmitted light of a small slit passes along the lens system 82A and the reflector 83A, and enters into the object lens 84A of a projection system. And only a desired angle is deflected by the prism 85A, and a slit image is formed in each detecting point.

[0118]The illumination-light study system 80A, the multi-slits plate 81A, the lens system 82A, the reflector 83A, the object lens 84A, and the prism 85A constitute the projection system of an oblique incidence light type focus detection unit. The solid line of the optical path ranging from the multi-slits plate 81A to the wafer W shown in drawing 8, The chief ray of the light transmitted from the small slit is expressed, and the dotted line in an optical path expresses with detecting point FB2a (or FB2b) the typical image formation beam of light SLf of the small

slit image formation light by which image formation is carried out.

[0119]The catoptric light of the small slit image formation light reflected with each detecting point on the wafer W passes along the prism 85B, the object lens 84B, the reflector 83B, and the lens system 82B, and image formation is again carried out with the light-receiving slit plate 81B. The prism 85B, the object lens 84B, the reflector 83B, and the lens system 82B are arranged in general symmetrically to said projection system. Ten small slits for light-receiving arranged corresponding to said small slit provided in the projection multi-slits plate 81A are formed in the light-receiving slit plate 81B. The light which transmitted the small slit for these light-receiving is received by the light-receiving device 80B. The light-receiving device 80B serves as two or more photoelectric detection elements.

[0120]As two or more photoelectric detection elements of the light-receiving device 80B, ten photoelectric detection elements are provided corresponding to the position of the small slit of the light-receiving slit plate 81B so that the focal position in the detecting point on a wafer can be detected separately. The light-receiving device 80B, the light-receiving slit plate 81B, the lens system 82B, the reflector 83B, the object lens 84B, and the prism 85B constitute the light-receiving system of an oblique incidence light type focus detection unit. The solid line of the optical path which faces to the light-receiving slit plate 81B from the wafer W shown in drawing 8 expresses the chief ray of the small slit usually reflected by the target with the wafer W. The dotted line in an optical path expresses the typical image formation beam of light RSf which faces to the light-receiving slit plate 81B from detecting point FB2a (or FB2b).

[0121]The projection system and light-receiving system which were shown in drawing 8 are attached to the metal members formed in one. The position of a component receives mutually and is correctly maintained by it. Metal members are being fixed so that it may not move to the lens barrel (body tube) of 1 / 4 reduction-projection-lens system PL. Another focus detection unit which comprised same method, It is arranged in the opposite hand of 1 4 reduction-projection-lens system PL, and a focal position can be separately detected now with ten detecting point FEna, FEnb (n= 1, 2, 3), FD1a, FD2a and FD1b which were shown in drawing 7, and FD2b.

[0122]About detecting point FC1a of said couple and FC1b which were shown in drawing 7, and detecting point FC2a of said couple and FC2b, It may be made to provide the focus detection unit of the oblique incidence light type which has each of the projection system arranged in the direction (direction which intersects perpendicularly to the space of drawing 8) of Y of drawing 7, and a light-receiving system in the both sides in the direction of X of 1 4 reduction-projection-lens system PL. As the focus detection point was shown in drawing 5, when it has been arranged, the focus detection unit of the oblique incidence light type shown in drawing 8 can be applied similarly.

[0123]Next, the scanning aligner to which automatic-focusing doubling / tilt control system of

the invention in this application are applied is explained according to the 3rd example of the invention in this application with reference to drawing 9. This example is applicable to the scanning aligner for substrates which has a big substrate of 300 mm, for example, a diameter, or a diameter beyond it. Said scanning aligner is provided with 1X projection optical system (namely, 1 time). Said projection optical system of 1X is formed in the combination (it stood in a line perpendicularly) of the tandem type of a 1st-step Dyson (Dyson) type projection imaging (KADADIOPUTORIKKU (reflective refraction)) system and a 2nd-step Dyson (Dyson) type projection imaging system. A 1st-step DAISON type (KADADIOPUTORIKKU) projection imaging system is provided with the following.
The prism mirrors PM1 and PM2 of a couple.
Lens system PL1.
Concave mirror MR1.
A 2nd-step DAISON type projection imaging system is provided with the following.
The prism mirrors PM3 and PM4 of a couple.
Lens system PL2.
Concave mirror MR2.
Such an aligner is indicated by United States patent (given to Swanson etc.) 5th and No. 298 or 939, for example.
[0124]In the aligner shown in drawing 9, the mask M provided as an original plate and the plate P provided as a photosensitive substrate are supported by the carriage 100 in one. By moving illumination-light IL so that it may see by drawing 9 to the projection view field of the projection optical system of 1X (single magnification), and the carriage 100 may be moved to the left or the right and the mask M and the plate P may be scanned (scan), The pattern provided in the mask M is transferred by the plate P as an erect image of 1X (single magnification).
[0125]In the case of the projection optical system for this type of aligners, by making the interval of the entrance plane of prism mirror PM1, and the surface of the mask M, and the interval of the emission face of prism mirror PM4, and the upper surface of the plate P into the minimum, It is desirable to decrease aggravation of image formation performance (various aberration and image distortion (image distortion)). If it puts in another way, and these intervals can fully be decreased, the design of the lens systems PL1 and PL2 arranged on optic-axis AX1 and AX2 will become easy. Therefore, in order to attain desired image formation performance, it is required to decrease prism mirror PM1, the interval between the masks M, and prism mirror PM4 and the interval between the plates P.
[0126]In consideration of this state, carry out focusing of the pattern image projected by this projection, and in order to carry out tilt adjustment of a pattern image, Exposure position off-axis type focus detecting system GDC and the prediction focus detecting systems GDL and GDR like the 1st example (drawing 3) or the 2nd example (drawing 7, drawing 8), As shown in

drawing 9, it is provided in the circumference of prism mirror PM4, and the surface of the plate P and optimal focal plane BFP can be correctly coincided in the exposure position just under prism mirror PM4 by moving the plate P to a Z direction and tilting directions slightly by this.
[0127]As shown in drawing 9, prediction focus detecting system GDL' and GDR', and exposure position off-axis type focus detecting system GDC' can be arranged around prism mirror PM1 by the mask M side so that the mask M may be faced. A slight gap in the focal error and tilt error of a field of the mask M which are illuminated by illumination-light IL to prism mirror PM1 by these focus detecting systems can be detected, and it can come, simultaneously / a Z direction] (focal gap of the image surface), A tilt gap (inclination to the image surface) of the optimal focal plane (namely, conjugate side of the reticle R) formed in the part which separated only predetermined working distance from prism mirror PM4 can be measured.
[0128]Therefore, in the aligner shown in drawing 9, it can adjust so that the image surface where image formation of the pattern of the mask M is projected and carried out by the projection optical system in the optimal state, and the surface of the plate P may receive mutually with high precision and may be in agreement during scanning exposure.
[0129]The aligner shown in drawing 9 can be constituted so that the mask M and the plate P may be set up perpendicularly. Drawing 10 is a perspective view of a typical structure of a scanning aligner. This scanning aligner was provided perpendicularly, namely, is provided with the carriage of every length. The carriage of every length holds the mask M and the plate P perpendicularly (namely, longitudinally), and moves the mask M and the plate P in one to a projection optical system, and it enables it to scan it (namely, scan). The scanning aligner which has the mask M and the plate P which were perpendicularly held in this mode is indicated by JP,8-162401,A, for example.
[0130]Reference of drawing 10 constitutes the whole scanning aligner of the type on the fixed base 120A every length. The fixed base 120A is arranged at the floor provided with the vibration isolation which intervened between four corner parts of the fixed base 120A, and floors. The side frame parts 121A and 121B are formed in the side part of the fixed base 120A so that it may set up perpendicularly (the direction of X). The mask M is formed inside the side frame part 121A. On the other hand, the plate P is formed inside the side frame part 121B. Therefore, the opening is formed in the side frame part 121A. The end of the lighting unit 122 is inserted in this opening of the side frame part 121A like a graphic display. The lighting unit 122 is provided with the optical system which illuminates the mask M by the illumination light for exposure, and performs alignment with a mask and a plate.
[0131]The guide base part 123 is formed in the fixed base 120A so that it may elongate to a scanning direction (the direction of Y) among the side frame parts 121A and 121B. The two straight guide rails 123A and 123B are formed in the guide base part 123 so that it may elongate in the parallel direction of Y mutually. Every length, the carriage 125 is supported by

the fluid bearing and the magnetic floating type bearing on the guide rail 123A and 123B so that reciprocation moving can be carried out in the direction of Y. The carriage 125 is driven in the direction of Y every length at a noncontact type with the two linear motors 124A and 124B arranged in parallel. The linear motors 124A and 124B are provided with the stator fixed to the guide base part 123.

[0132]The carriage 125 is provided with the mask side carriage part 125A and the plate side carriage part 125B every length. The mask side carriage part 125A is perpendicularly formed by the inside of the side frame part 121A, in order to hold the mask M. The plate side carriage part 125B is perpendicularly formed by the inside of the side frame part 121B, in order to hold the plate P. The mask table 126A is formed in the mask side carriage part 125A. Holding the mask M, the mask table 126A can move the mask M in the direction of X, or the direction of Y slightly in an XY plane, or can move the mask M in the rotation (theta) direction slightly. The mask table 126A can move the mask M to a Z direction slightly, holding the mask M. On the other hand, the plate stage 126B is established in the plate side carriage part 125B. Holding the plate P, the plate stage 126B can move the plate P in the direction of X, or the direction of Y slightly in an XY plane, or can move the plate P in the rotation (theta) direction slightly. The mask table 126A can move the plate P to a Z direction slightly, holding the plate P.

[0133]Projection optical system PL which is indicated by JP,8-162401,A mentioned above is used in this example. Projection optical system PL is constituted by arranging the 1X (1 time) erect-image type (for example, 7 sets) double DAISON (Dyson) system of two or more sets in the direction which intersects perpendicularly in the direction of X. Within the casing, two or more sets of double DAISON (Dyson) systems are together put in one, and are accommodated. The casing serves as about T type, seeing at XZ flat surface. Projection optical system PL constituted in this way is attached by hanging from the upper edge of the side frame parts 121A and 121B which countered. The predetermined test working distance of the mask M and the plate P is maintained by it.

[0134]In as shown in drawing 9] all the casings of projection optical system PL, It is provided in the mask M side so that focus detecting system GDC', GDL', and GDR' by the side of the mask M may face the mask M, and it is provided in the plate P side so that the focus detecting systems GDC, GDL, and GDR by the side of the plate P may face the plate P. The prediction focus detecting system GDL, GDL', and the detecting point demarcated by GDR and GDR' can be set up it be in agreement with the projection view field of two or more sets of double DAISON (Dyson) systems, or can be arranged at the predetermined intervals irrespective of arrangement of a projection view field.

[0135]Drawing 11 is a perspective view of an example of focus detecting system GDC' by the side of the mask M provided in the casing of projection optical system PL shown in drawing 10, and the layout of the detector of GDL' and GDR'. projection view field DF1 effective of two or

more sets of double DAISON (Dyson) systems, DF2, DF3, DF4, and DF5 ..... is set up in the direction of X which intersects perpendicularly with a scanning direction as a field of long and slender trapezoidal shape. The projection view field DFn (n 1, 2, 3 ...) of trapezoidal shape is arranged so that the projection view field of the trapezoidal shape of a pair of double DAISON (Dyson) system which each adjoins may see in the direction of X and only the inclination side may lap mutually.

[0136]Although only the projection view field DFn established in the mask M side is illustrated by drawing 11, the projection view field by the side of the plate P is arranged similarly. For example, projection view field DF2 shown in drawing 11 is demarcated by the double DAISON (Dyson) system containing two concave mirror MR2a and MR2bs as shown in drawing 9. Projection view field DF4 is demarcated by the double DAISON (Dyson) system containing two concave mirror MR4a and MR4b.

[0137]it was shown in drawing 11 -- as -- the prediction focus detecting system GDL -- 'detector GDA1 of ', and GDB1'GDB2 -- with '..., GDA2' (GDA2' is not shown in drawing 11). prediction focus detecting system GDR -- 'detector GDD1 of ', and GDE1'GDE2 -- '..., GDD2' (GDD2' is not shown in drawing 11) are arranged at the both sides (they are a front side and the backside to a scanning direction) of two or more projection view fields DFn. Exposure position focus detector GDC1' and GDC2' (drawing 11 is not [detector GDC2' shown) are arranged to the both ends of the array (arrangement) of two or more whole projection view fields DFn which can be set in the direction of X which intersects perpendicularly to a scanning direction.

[0138]Each of the focus detector mentioned above serves as an air micrometer type static electricity gap sensor, for example. Each of the focus detector mentioned above can also be instead used as an oblique incidence light type focus detector. Although only the focus detector which detects with the mask M is illustrated by drawing 11, two or more detectors are arranged in a similar manner at the focus detecting systems GDC, GDL, and GDR so that the plate P can be detected.

[0139]The controllers KD1 and KD2 for which adjusts the various optical characteristics of two or more sets of double DAISON (Dyson) systems carrying out are formed in the side part of the casing of projection optical system PL shown in drawing 11. Therefore, supposing the position of the optimal focal plane by the side of the mask M or the plate P changes with optical characteristic regulation in the Z direction of drawing 11, The mechanism, i.e., the mechanism in which the mechanical (it is optical) focal offset detected as optimal focal plane by each focus detector is set up, in which a Z direction position is adjusted is formed.

[0140]This mechanism can use the position of the focus detector in a Z direction as the mechanism adjusted mechanically, for example so that the length of an optical path may be changed optically. Or this mechanism can use the position evaluated as optimal focal position

as the mechanism optically adjusted to a Z direction with a focus detector, for example so that the length of an optical path may be changed optically. Instead, a mask or a plate is automatically adjusted so that focusing can be performed to a Z direction according to the detecting signal showing a focal error. And offset is added to the moved position in a Z direction.

[0141]Next, the 4th example in connection with the invention in this application is described with reference to drawing 12. This example is applicable to the device which performs projection exposure, dipping the projection end of projection lens system PL in a fluid, as mentioned above. Drawing 12 is a sectional view of the portion from the end of projection lens system PL to the wafer holder WH among said devices.

[0142]Positive lens element LE1 provided with the flat undersurface Pe and the convex upper surface] is being fixed to the end of projection lens system PL inside a lens barrel (body tube). The undersurface Pe of this positive lens element LE1 is finish-machined so that it may become the end face at the very end of a lens barrel, and the same flat surface. As a result, disorder of the flow of fluid LQ is the minimum. The detector which becomes a lens barrel end of projection lens system PL dipped in fluid LQ from the same prediction focus detecting systems GDL and GDR and exposure position focus detecting system GDC as what was shown in drawing 1 is attached. As a result, the end of those very ends is dipped in fluid LQ.

[0143]Two or more attraction faces 113 which draw the rear face of the wafer W by vacuum suction are formed in the central inner bottom of the wafer holder WH. If it explains more concretely, the attraction face 113 is provided with two or more band-like circular lands. The height of the band-like circular land is about 1 mm. A band-like circular land has a predetermined pitch in the diametral direction of the wafer W, and is mutually formed in it concentrically. Each of the slot formed in the center portion of a circular land is open for free passage in the pipe 112 of the wafer holder WH. The pipe 112 is connected to the vacuum source which performs vacuum suction.

[0144]The undersurface Pe of positive lens element LE1 which is in the end of projection lens system PL in this example, and the upper surface (.) of the wafer W in punctate optimal Or the interval between the upper surfaces of the auxiliary plate part HRS (substantial test working distance), i.e., the thickness of fluid LQ in which a projection optical path is formed, is set to 5 mm or less than it. therefore, the depth Hq of fluid LQ filled by the wafer holder WH -- this thickness (5 mm or less than it) -- twice -- or it can enlarge several times. And the height of the wall LB formed at right angles to the circumference end of the wafer holder WH is about 10 mm thru/or 25 mm. Therefore, in this example, the total volume of fluid LQ which the thickness of fluid LQ in the image formation optical path corresponding to the working distance of projection lens system PL decreased, and was filled by the wafer holder WH as a result becomes smaller, and the temperature control of a fluid [LQ is easier for it.

[0145]In the field of fluid LQ in which a projection optical path is formed, when exposing light passes through the field, lighting energy is absorbed. as a result, radiant heat change is alike and takes place easily. If the depth Hq of fluid LQ is small, the rise in heat by such radiant heat change will arise easily, and the adverse effect that the stability of temperature control decreases will arise. In such a case, in order to set and to vanish the influence of the radiant heat change in an extensive liquid layer, a good effect can be acquired by setting the value of the depth Hq of fluid LQ to working distance several times the value of being substantial.
[0146]In order to form the focus detecting systems GDL, GDR, and GDC in the projection system of a dipping type as shown in drawing 12 as a detection system optical type, The projection beam (light flux) which enters into the surface of the wafer W or the surface of the auxiliary plate part HRS aslant, and the beam reflected from this surface have prevented crossing the interface between fluid LQ and air. Therefore, an example of a focus a tilt detection system suitable for a projection type such dipping-type] aligner is explained with reference to drawing 13.
[0147]Drawing 13 shows the composition of the focus detecting system GDL arranged near projection lens system PL. Other focus detecting systems GDR and GDC are constituted the same with the focus detecting system GDL being constituted. In drawing 13, the same component as the component shown in drawing 12 is shown by the same reference mark and the reference number.
[0148]Reference of drawing 13 is fixing the prism mirror 200 formed by the glass block near the periphery of projection lens system PL. The prism mirror 200 is provided with the lower part, and the lower part is dipped in fluid LQ. The prism mirror 200 is provided with the reflectors 200a and 200b. A part of reflectors 200a and 200b are dipped in fluid LQ. The prism mirror 200 is provided with the flat faces 200c and 200d again. The beam projected and the beam reflected pass along the flat faces 200c and 200d, and progresses into fluid LQ from the glass of the prism mirror 200, or progresses into glass from fluid LQ. The prism mirror 200 is provided with the flat upper surface again.
[0149]The multi-slits plate 205 lets a condenser lens or the cylindrical shape lens 203 pass, and is illuminated in optical (it has wavelength which does not have actinism to resist on wafer W) LK from the light source 202 like a light emitting diode (LED) or a laser diode (LD). Of this, the projection beam a focus for tilt detection is formed. Two or more penetration slits corresponding to the detecting points (field) FAn and FBn of the focus detecting system GDL are formed in the multi-slits plate 205. It is reflected by the beam splitter 207, and the light from each penetration slit enters into the object lens 209, and is converged as an image formation beam which forms a slit image in the upper surface of the wafer W.
[0150]The image formation beam which came out of the object lens 209 goes into the prism mirror 200 through the upper bed side of the prism mirror 200, It reflects like usual according to

the reflector 200a, goes into fluid LQ through the flat face 200c, and enters into the surface of the wafer W from across, and the wafer W is illuminated by this. wafer W be alike -- the ****** (ed) beam goes into the prism mirror 200 through 200 d of flat faces of an opposite hand, according to the reflector 200b, through the upper bed side of the prism mirror 200, it is reflected like usual, and comes out of the prism mirror 200, and progresses. This reflected optical beam passes the object lens 211, and is reflected by the reflective mirror 213 arranged at the pupil position of the object lens 211.

[0151]The beam reflected by the reflective mirror 213 goes to a counter direction through the object lens 211, progresses through the reflector 200b and 200 d of flat faces of the prism mirror 200, and illuminates the wafer W again. With the wafer W, it progresses through the flat face 200c and the reflector 200a of the prism mirror 200, and the optical beam reflected again passes the beam splitter 207, and enters into the photoelectric detector 215. The photoelectric detector 215 serves as two or more elements which receive the light corresponding to the multi-slits plate 205. The photoelectric detector 215 outputs independently the detecting signal about the detecting points FAn and FBn, respectively.

[0152]Therefore, the focus / tilt detection system shown in drawing 13 are arranged as a double path system in which the projection beam reflected by the wafer W is re-reflected by the wafer W. Therefore, its focus tilt detection system can be provided with higher sensitivity about error detection of the surface position of the wafer W in a Z direction as compared with single optical path systems.

[0153]In this example, the glass block (prism mirror 200) is provided in the very end of the focus / a tilt detection system, and that glass block is positioned so that that part may be dipped in fluid LQ.As a result, a projection beam and a reflective beam do not pass what kind of interface between fluid LQ and air. Therefore, thereby, the optical path of the stable beam is established. The effective length of the optical path of fluid LQ which a projection beam or a reflective beam passes can avoid the fall of accuracy by the temperature change of fluid LQ, when decreasing by the prism mirror 200 and measuring Z position by it.

[0154]The example of change of the structure of the wafer holder WH shown in drawing 1 and drawing 5 is explained with reference to drawing 14 and drawing 15. Drawing 14 is a sectional view of the wafer holder WH attached to the projection aligner which exposes a dipping type. In this example, Z-drive unit 220 in which slight movement regulation like a piezoelectric element is possible is formed. Z-drive unit 220 can move slightly the auxiliary plate part HRS surrounding the attraction face 113 which supports the wafer W. Z-drive unit 220 in which slight movement regulation is possible moves the auxiliary plate part HRS to a Z direction only Stoke with a divisor of 10 micrometers.

[0155]If the difference between the height of the surface of the wafer W provided on the attraction face 113 of the wafer holder WH and the height in the Z direction of the surface of

the auxiliary plate part HRS is larger than tolerance, This Z-drive unit 220 can be used, the height of the surface of the auxiliary plate part HRS can be amended, and said difference can be decreased to a value smaller than said tolerance.

[0156]As mentioned above with reference to drawing 5, the surface of the auxiliary plate part HRS, When shot region SA1 of the periphery of the wafer W is exposed, it is functioning as an alternative detection surface of focus detection point FA1 (or FA2) provided in the outside of the wafer W, FC1 (or FC2), and FD1 (or FD2) business. However, when shot region SA2 inside the wafer W (refer to drawing 5) is exposed, these focus detection points are positioned on the wafer W. Focus detector GDA1 which has a detecting point which is not monopolistically positioned on [one] the surface of the auxiliary plate part HRS and the surface of the wafer W, GDA2, GDC1, GDC2, GDD1, and GDD2, therefore, Z position must be correctly measured on [each] these surfaces. That is, the position in the Z direction of the surface of the auxiliary plate part HRS and the surface of the wafer W needs to be located in the linearity focal time base range of each focus detectors GDAn, GDCn, and GDDn.

[0157]For example, if 10 micrometers of linearity focal time base ranges of a focus detector become, Z position gap of the surface of the auxiliary plate part HRS and the surface of the wafer W will be restricted within the limits of several micrometers. However, the thickness of a wafer changes by the common difference determined by a standard [for SEMI (Semiconductor Equipment and Materials International) one. It is difficult to restrict the thickness of all the usable wafers within the limits of several micrometers.

[0158]Therefore, when it is drawn by the wafer W to the wafer holder WH shown in drawing 14 before being exposed, The difference between Z position (for example, center portion of a circumference shot region) of a portion with the suitable wafer W surface and Z position of the surface of the auxiliary plate part HRS is measured by using one of the focus detecting systems (GDL, GRD, GDC), and exposure is performed after that. If the difference has crossed tolerance level (for example, several micrometers), the height of the auxiliary plate part HRS will be adjusted by controlling Z-drive unit 220 which was shown in drawing 14 and in which slight movement regulation is possible so that the difference may be settled in tolerance level. Since the wafer holder WH shown in drawing 14 is filled with fluid LQ, water proofing of the Z-drive unit 220 in which slight movement regulation is possible is carried out, and the enter lump to the unit concerned of a fluid is prevented by this.

[0159]Next, the composition shown in drawing 15 is explained. Drawing 15 is a sectional view of the example of change of a structure provided with the wafer holder WH and the ZL stage 30 suitable for exposing a wafer in the atmosphere. The component corresponding to the component shown in drawing 14 is shown by the same reference mark and the reference number. Reference of drawing 15 constitutes the wafer holder WH as a zipper. Only the attraction face 113 for supporting the wafer W is formed in the wafer holder WH. The wafer

holder WH is being fixed to the ZL stage 30.

[0160]The auxiliary plate part HRS is attached to the ZL stage 30 with Z-drive unit 220 in which slight movement regulation is possible. Z-drive unit 220 intervenes between the auxiliary plate part HRS and the ZL stage 30. The three Z-actuators 32A which drive the ZL stage 30 in a Z direction and the direction of tilt motion, Each operation point PV of 32C and 32B (not shown [32B to drawing 15) is set as the point of the periphery of the ZL stage 30 in the substantially same height as the wafer clamp face (attraction face 113) of the wafer holder WH.

[0161]The height of the auxiliary plate part HRS is the same method as having been shown in drawing 14, and is adjusted by the height of the upper surface of the wafer W by using Z-drive unit 220 in which slight movement regulation is possible as shown in drawing 15. The height of operation point PV is set as the same height as a wafer surface. The structure of the ZL stage 30 and the structure of the Z-actuators 32A, 32C, and 32B which were shown in drawing 15 are applicable also to the aligner shown in drawing 1. Focusing suitable for a dipping-type projection aligner or the projection exposure method of a dipping type and a tilt motion stage can be formed by attaching the wafer holder WH of drawing 14 to the ZL stage 30 of drawing 15.

[0162]The invention in this application explained application to an exposure device. However, the example mentioned above can be changed by various methods, without leaving the range of the invention in this application. For example, in the case of the aligner which performs projection exposure in the atmosphere, the focus detecting systems GDL, GDR, and GDC can be provided with an electric capacity type gap sensor or an air micrometer type gap sensor. . The invention in this application uses the pulsed light (248 nm) emitted from g line (463 nm) or i line (365 nm) emitted from a mercury discharge lamp, or a KrF excimer laser, for example as exposing light. It is applicable to the projection aligner of every type a step-and-repeat type, a step and scan type, and "1X (1 time) scanning type.

[0163]While the working distance of the projection optical system attached to the projection aligner is set as the very small value according to the invention in this application, Exact focusing and tilt control in an exposure position can be realized, the amendment of various aberration and the amendment of distortion in the optical design of a projection optical system become easy by it, and size of the transparent optical element positioned near the image surface can be especially made small.

[0164]Each of focusing / a tilt control system in connection with the example which the invention in this application mentioned above is applicable to a projection aligner fixed type. However, the invention in this application can be applied also to the focus tilt detection system for a beam processing (manufacture) device, a drawing device, test equipment, etc., and is not limited to semiconductor manufacture again. The optical or electrooptic objective lens system is provided in these beam processing devices, a drawing device, and test

equipment. The invention in this application is applicable to said optical or electrooptic objective lens system as a focus detecting system for detecting the focus on a substrate, the specimen, or a workpiece.

[0165]Drawing 16 shows the composition of the focus detecting system applied to the objective lens optical system of the device which draws a pattern on the device into which a workpiece is processed with a laser beam or an electron beam, or a workpiece. Drawing 17 shows the flat layout of the detecting point of the focus detecting system shown in drawing 16.

[0166]If drawing 16 is referred to, by the scanning mirror 300, the beam LBW for processing or drawing will be deflected in one dimension or in two dimensions, and will pass along the lens system 301, the fixed mirror 302, and the lens system 303, and will enter into the beam splitter 304. It is reflected by the beam splitter 304 and the beam LBW enters into the objective lens system 305 of the high resolution which has slight working distance. The beam LBW is condensed according to the objective lens system 305 by the small spot which has the predetermined shape (for example, variable-length rectangle shape) on workpiece WP.

[0167]Workpiece WP is being drawn and fixed to the same wafer holder WH as a thing as shown in drawing 14 or drawing 15. The auxiliary plate part HRS is attached to the wafer holder WH in one around workpiece WP. It is being fixed to the XYZ-stage which is not illustrated and this XYZ-stage of the wafer holder WH is movable in two dimensions [direction / which sees by a horizontal direction or drawing 16 and intersects perpendicularly to space]. The wafer holder WH moves perpendicularly (the direction of Z-) slightly again, and has come to be able to do focusing.

[0168]The optical fiber 310 for emitting the illumination light for observation, alignment, or collimation doubling to the device shown in drawing 16, The beam splitter 311 and the lens system 312 which show the above-mentioned beam splitter 304 to the illumination light, and the light-receiving devices (for example, a photo multiplier, an image pick-up tube, CCD, etc.) 314 are formed. The light-receiving device 314 can detect now in photoelectricity catoptric light, light scattered about and diffracted, etc. which were obtained through the objective lens system 305 from workpiece WP.

[0169]The prediction focus detecting systems GDL and GDR and processing position focus detecting system GDC are provided in the circumference of the objective lens system 305. Drawing 17 shows the flat layout of the detecting point of the focus detecting system arranged around the view 305A of the objective lens system 305, and the view 305A. For convenience, the center of the view 305A is set as the starting point of an XY coordinate system. The rectangle region of the view 305A shows the range which the spot of this beam LBW scans (namely, scan) according to the deviation of the beam LBW caused by the scanning mirror 300.

[0170]Focus detector GDA1, GDBn, and GDA2 are set up so that it may be arranged on the

left-hand side side of the view 305A of an objective lens system and detecting point FA1, FB1, FB2, FB3, and FA2 may become a sequence parallel to a Y-axis as a result. Focus detector GDD1, GDEn, and GDD2 are set up so that it may be arranged on the right-hand side side of the view 305A and detecting point FD1, FE1, FE2, FE3, and FD2 may become a sequence parallel to a Y-axis as a result.

[0171]On the other hand, focus detector GDC1 is provided above the view 305A. And focus detector GDC1 is set up so that three detecting point FD1a, FD1b, and FD1c may be arranged on a line parallel to the X-axis through the two detecting points FA1 and FD1. On the other hand, the view 305A is caudad established for focus detector GDC2. And focus detector GDC2 is set up so that three detecting point FD2a and FD2bs, and FD2c may be arranged on a line parallel to the X-axis through the two detecting points FA2 and FD2. In this example, while workpiece WP moves in the direction of X, focus detector GDA1 of a lot, GDBn and GDA2, and focus detector GDD1 of a lot, GDEn and GDD2 are chosen as a focal read-ahead capability. On the other hand, while workpiece WP moves in the direction of Y, a focal read-ahead capability is attained by choosing focus detector GDA1 of a lot, GDC1 and GDD1, and focus detector GDA2 of a lot, GDC2 and GDD2. By changing the focus detector GDBn, GDC1, GDC2, and the detecting point of GDEn, this example is constituted so that the focus of a processing position can be detected. For example, when workpiece WP is missing from a right-hand side side from the left-hand side side of drawing 16 and moves along with the X-axis, Predicting using detecting point FA1, FB1, FB2, FB3, and FA2. Among three pairs of detecting points which consist of detecting point FD1a and FD2a, detecting point FD1b and FD2bs, and detecting point FD1c and FD2c, the detecting point of a couple can be chosen in order to detect the focus of a processing position.

[0172]It has intention of this composition so that the following effect can be attained. Namely, the spot position of the object for processing or the optical beam LBW for drawing changes in the scanning range 305B. Therefore, when the spot of the optical beam LBW is positioned by the leftmost end of the scanning range 305B as shown in drawing 17 for example, two detecting point FD1a and FD2a can be chosen, and focus detection of a processing position can be performed. When the spot of the optical beam LBW is positioned by the rightmost end of the scanning range 305B, two detecting point FD1c and FD2c can be chosen, and focus detection of a processing position can be performed.

[0173]In this method, the reproducibility and accuracy of focus control or tilt control are improved. The electrode holder WH shown in drawing 16 moves in the direction of focusing (Z), and the direction of tilt motion slightly on an XY stage. What was shown in drawing 4 can be used as the drive system and control system for performing this movement, without making a substantial change.

[0174]As mentioned above, the focus detecting system shown in drawing 16 and drawing 17, It

is constituted so that focal prediction detection can be performed in each of the two-dimensional movement direction of workpiece WP, and so that the focus detection point about a processing position can choose according to the position of the beam spot in the view 305A. As a result, even the periphery of workpiece WP is precisely processed, where focusing is made correctly (image formation), or pattern image formation is performed on workpiece WP in such the state.

[0175]The outline of the test equipment which can apply the focus tilt detection system of the invention in this application is explained with reference to drawing 18. Drawing 18 shows the example of the device which inspects optically the defect of the circuit pattern of the semiconductor device and LCD device which were formed in the defect of the pattern copied by the mask and reticle for photo lithography, or the substrate.

[0176]By expanding an inspected pattern through an objective lens optical system these days, By forming the enlarged image of the expanded inspected pattern with a CCD camera etc., The art of inspecting the quality of the inspected pattern formed in the specimen (substrate), or inspecting foreign matters, such as heterogeneous particles, and existence of damage and nonexistence is positively introduced into this kind of test equipment by analyzing the picture signal acquired from such an image.

[0177]In such a case, it is important to improve accuracy so that the image of an inspected pattern may be expanded correctly. Therefore, the objective lens system in which resolution can form an image by the minimum high, large aberration and distortion of view size moreover is required. Such an objective lens system is usually designed as a SURUZA lens (TTL) type so that working distance may be small and focus detection may naturally be performed through an objective lens system. However, a TTL optical focus detecting system will be accompanied by the problem which restricts detection sensitivity (variation of a detecting signal to the error at the time of carrying out focusing of the specimen). It is because the numerical aperture (NA) of an objective lens system is restricted.

[0178]Supposing the TTL focus detecting system is formed so that the light which has the wavelength of the checking illumination light and different wavelength may be used, when performing the optical design of an objective lens system, aberration must be amended in consideration of the wavelength band region of the checking illumination light, and the wavelength band region of the focus detection illumination light. In such a case, a lens cannot necessarily be designed the optimal to the checking illumination light.

[0179]Then, two or more sets of focus detecting systems GDC, GDL, and GDR can be formed in the circumference of the object lens 330, and, thereby, it can inspect now by the same method as the focus detecting system shown in drawing 16 and drawing 17 as shown in drawing 18. Specimen WP which should be inspected serves as a mask in which pattern Pa was formed in the undersurface, for example. Specimen WPs are the peripheral edges and are

supported by the stage 331 of the shape of a movable frame in the direction of two dimensions. The stage 331 is provided with the opening. The object lens 330 is in the state which turned to the upper part, and is attached to the base member 332 to which it shows movement of the stage 331. The enlarged image of the local area of pattern Pa passes along the beam splitter 334 and the lens system 335, and carries out image formation to the image surface of the imaging device 336.

[0180]In the opposite hand of specimen WP, the condenser lens 338 of an illumination-light study system is arranged at the axis AX and the same axle of the object lens 330. It progresses through the condenser lens 341, the lighting field diaphragm 342, and the lens system 343, and the illumination light from the optical fiber 340 enters into the condenser lens 338. The field corresponding to the view of the object lens 330 is illuminated with uniform illumination among specimen WPs by it.

[0181]In the composition mentioned above, the focus detecting systems GDC, GDL, and GDR are attached to the base member 332 together with the object lens 330 so that pattern Pa may be faced with the up side. Two or more focus detectors (two or more detecting points) are formed in the focus detecting systems GDL and GDR which can be predicted. The focus detector of the couple is formed in focus detecting system GDC detectable with an inspection point on the other hand at least.

[0182]It may enable it to move specimen WP on the stage 331 perpendicularly in accordance with the optic axis AX in the focus detecting system shown in drawing 18, Or based on the focal position information detected by the focus detector, it is made to carry out by using a control circuit as shown in drawing 4 a tilt. However, in the test equipment shown in drawing 18, if only the effect that the quality of the enlarged image of pattern Pa by which image formation was carried out with the imaging device 336 becomes high is acquired, it is enough. Therefore, the focusing device 352A or 352B for moving slightly the object lens 330 or the lens system 335 in accordance with the optic axis AX can be formed instead of a means to move specimen WP perpendicularly.

[0183]The test equipment which positions mask pattern Pa provided as a specimen WP so that it may be suitable caudad is explained with reference to the example of drawing 18. Needless to say, this example is directly applicable also to the test equipment which turned pattern Pa upwards and turned the object lens downward. The image which pattern Pa was delivered is inspected in the device shown in drawing 18 by the transmitted illumination system provided in the same axle.

[0184]However, said transmitted illumination system can be changed so that the reflected illumination light of the same axle may be introduced in the direction of the arrow 350 of drawing 18 through the beam splitter 334. In such a case, the enlarged image received by the imaging device 336 is formed by carrying out image formation of the catoptric light from pattern

Pa.

[0185]Other methods can also be used. In the method, the spatial filter provided with the transparent part which has desired shape is provided in the position of the Fourier transform flat surface formed in the optical path of an illumination-light study system, or its image formation optical system dismountable. It has come to be able to carry out the image formation of the light field image or dark field image of pattern Pa to the imaging device 336 selectively thereby.

[0186]This indication is illustrated and the invention in this application is not limited to this indication. Another example of change for a person skilled in the art is clear from a viewpoint of this indication, and this example of change is included in the range of the attached claim.

[Translation done.]

* NOTICES

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings
[Drawing 1 Drawing 1 is a diagram showing the scanning projection aligner (aligner) in the 1st example of the invention in this application.
[Drawing 2 Drawing 2 is an abbreviated perspective view for explaining a scanning sequence.
[Drawing 3 Drawing 3 is an abbreviated perspective view of arrangement of the focus detecting system established near the end of a projection lens system shown in drawing 1.
[Drawing 4 Drawing 4 is a circuit block diagram of AF control unit circuit structure shown in drawing 1.
[Drawing 5 Drawing 5 is a top view of the physical relationship between the projection view field on the wafer of the device shown in drawing 1, and the sensor for focusing.
[Drawing 6 Drawing 6 A is a diagram of the focusing operation of a device and tilt operation which were shown in drawing 1. Drawing 6 B is a diagram of the focusing operation of a device and tilt operation which were shown in drawing 1. Drawing 6 C is a diagram of the focusing operation of a device and tilt operation which were shown in drawing 1. Drawing 6 D is a diagram of the focusing operation of a device and tilt operation which were shown in drawing 1.
[Drawing 7 Drawing 7 is a top view of the layout of the detection area of the focus a tilt detection system in the 2nd example of the invention in this application.
[Drawing 8 Drawing 8 is a side view of the layout of the example of change of the focus a tilt detection system shown in drawing 7.
[Drawing 9 Drawing 9 is an approximate line figure of the 3rd example of the invention in this application where the invention in this application is applied to a scanning exposure device (scanning aligner).
[Drawing 10 Drawing 10 is a **** figure of a carriage every which is applied to the scanning aligner shown in drawing 9] length.

[Drawing 11 Drawing 11 is a perspective view of the projection optical system and focus detecting system which were provided in the projection aligner shown in drawing 9.
[Drawing 12 Drawing 12 is a sectional view of the 4th example of the invention in this application when the composition of the invention in this application is applied to a dipping type projection aligner.
[Drawing 13 Drawing 13 is a diagram showing the example of the optical-path layout of a focus / a tilt detection system suitable for a dipping type projection aligner.
[Drawing 14 Drawing 14 is a sectional view of the example of change of a wafer holder.
[Drawing 15 Drawing 15 is a sectional view of the example of change of a wafer holder.
[Drawing 16 Drawing 16 is a diagram by which the focus detection sensor of the invention in this application is applied and in which showing one example of a manufacturing installation, an image formation device, or a drawing device.
[Drawing 17 Drawing 17 is a top view showing the typical layout of the focus detecting system applied to the device shown in drawing 16.
[Drawing 18 Drawing 18 is the diagram showing roughly the structure of typical test equipment where the focus / tilt detection system of the invention in this application are applied.
[Description of Notations
10 Illumination system 11 Mirror
12 Condensing lens system 13 Columnar structure object
14 Reticle stage 15 Motor
16 Moving mirror 17 laser-interferometer system
20 Reticle stage controller
25 Main controller 30 ZL stage
31 Moving mirror 32A Z-actuator
32B Z-actuator 32C Z-actuator
33 Laser interferometer 34 XY stages
35 Wafer stage controller
36 Drive motor 52 Position supervisory circuit
54 The 1st computer 56 The 2nd calculation and store circuit
58 The 3rd calculation and drive circuit 80A Illumination-light study system
80B Light-receiving device 81A Multi-slits plate
81B Light-receiving slit plate 82A lens system
82B Lens system 83A Reflector
83B Reflector 84A object lens
84B Object lens 85A Prism
85B Prism 100 Carriage
112 Pipe 113 Attraction face

120A Fixed base 121A Side FUMU part
121B Side FUMU part 122 lighting units
123 Guide base part 123A Guide rail
123B Guide rail 125A The mask side carriage part
125B The plate side carriage part 126A Mask table A
126B Plate stage 200 Prism mirror
200a Reflector 200b Reflector
200c Flat face 200 d Flat face
202 Light source 205 Multi-slits plate
207 Beam splitter 209 object lenses
211 Object lens 213 Reflective mirror
215 Photoelectric detector 220 Z-drive unit
300 Scanning mirror 301 lens systems
302 Fixed mirror 303 lens systems
304 Beam splitter 305 objective lens systems
310 Optical fiber 311 Beam splitter
312 Lens system 314 Light-receiving device
330 Object lens 331 Stage
332 Base member 335 lens systems
334 Beam splitter 336 Imaging device
341 Condenser lens 342 Lighting field diaphragm
343 Lens system 338 Condenser lens
352A Adjusting device 352B Adjusting device
AX Optic axis Cp Image vision field
Ep Exit pupil FA1 detecting point
FB1 detecting point FB2 detecting point
FB3 detecting point FA2 detecting point
FC1 detecting point FC2 detecting point
GDL Focus detecting system GDR Focus detecting system
GDA1 Detector GDA2 Detector
GDB1 Detector GDB2 Detector
GDB3 Detector GDD1 Detector
GDD2 Detector GDE1 Detector
GDE2 Detector GDE3 Detector
GDC Focus detecting system GDC1 Detector
GDC2 Detector HRS auxiliary plate part
IA Pulse illumination light IL Illumination light

ILF Illumination light LGa Front group lens system
LGb Back group lens system LLa Straight line
LLb Straight line LLc Extension wire
LE1 positive-lens element LQ Fluid
LB Wall LK Light
LBW Beam M Mask
MR1 Concave mirror MR2 Concave mirror
MR2a Concave mirror MR2b Concave mirror
NT notch P Plate
Pa circuit pattern region Pe The flat undersurface
PL projection lens system PM1 Prism mirror
PM2 Prism mirror PM3 Prism mirror
PM4 Prism mirror PV Operation point
R Reticle RSf Image formation beam of light
SAa shot region SAb shot region
SB Cover belt SI Projection image
SLf Image formation beam of light W Wafer
WH Wafer holder

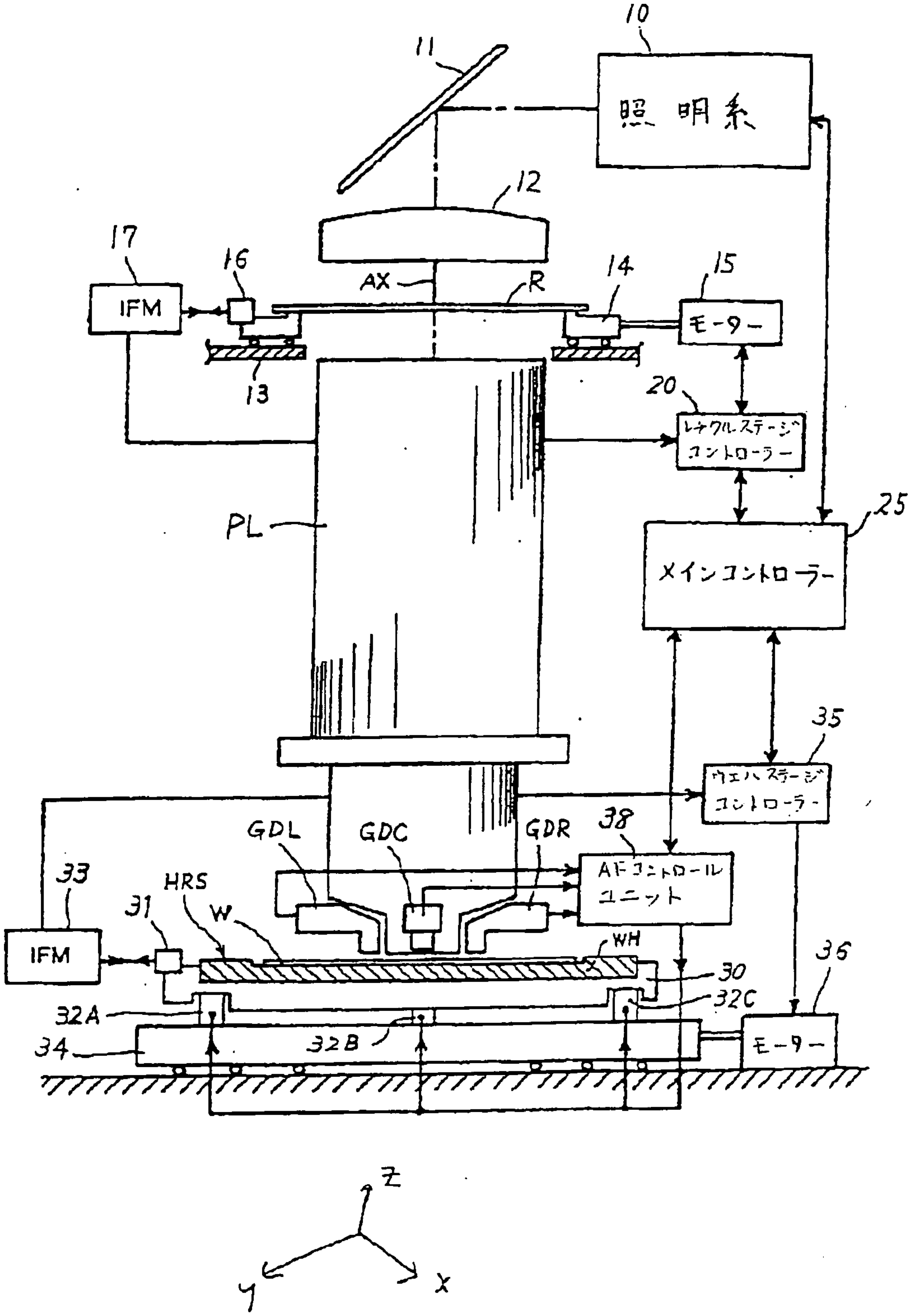
[Translation done.]

* NOTICES

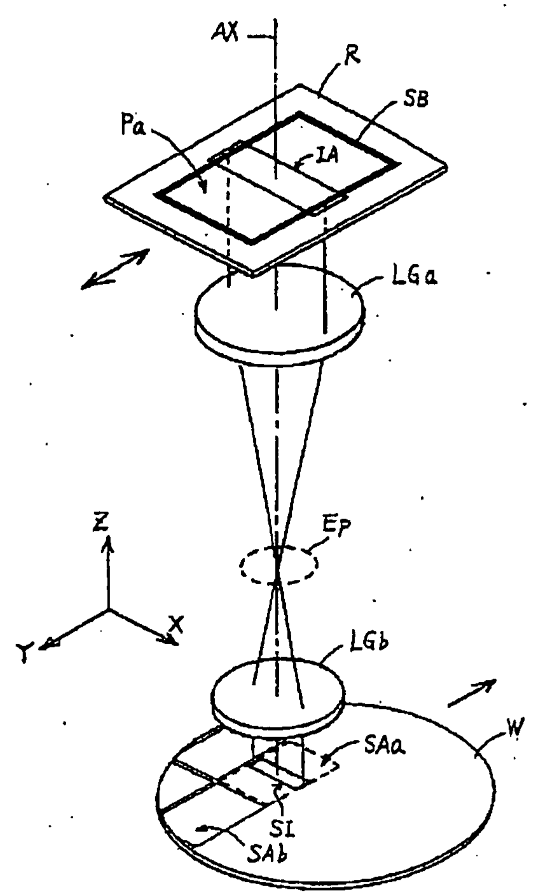
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 1


10
照明系
11
12
17
16
14
15
IFM
AX
R
モーター
13
20
レチクルステージコントローラー
PL
25
メインコントローラー
35
ウエハステージコントローラー
GDL
GDC
GDR
38
AFコントロールユニット
33
HRS
31
W
WH
IFM
30
32C
32A
36
34
32B
モーター
Z
Y
X

[Drawing 2



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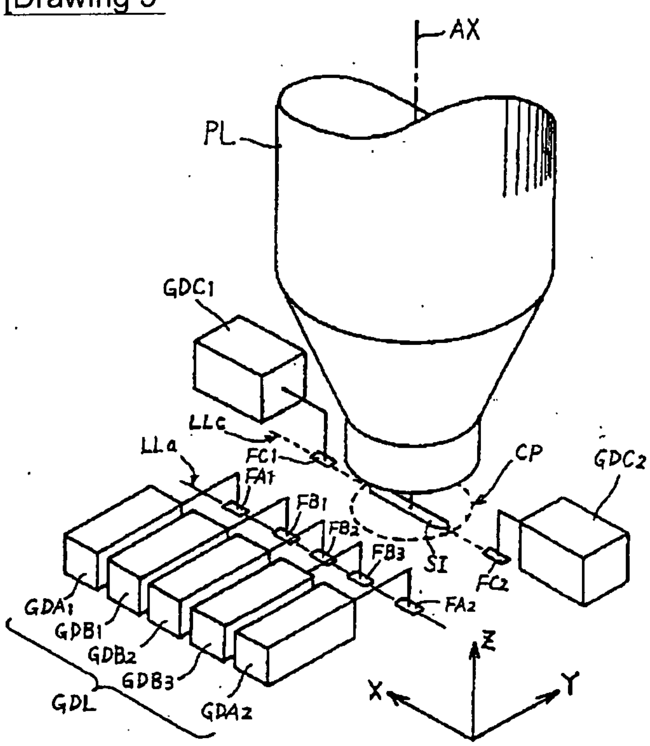

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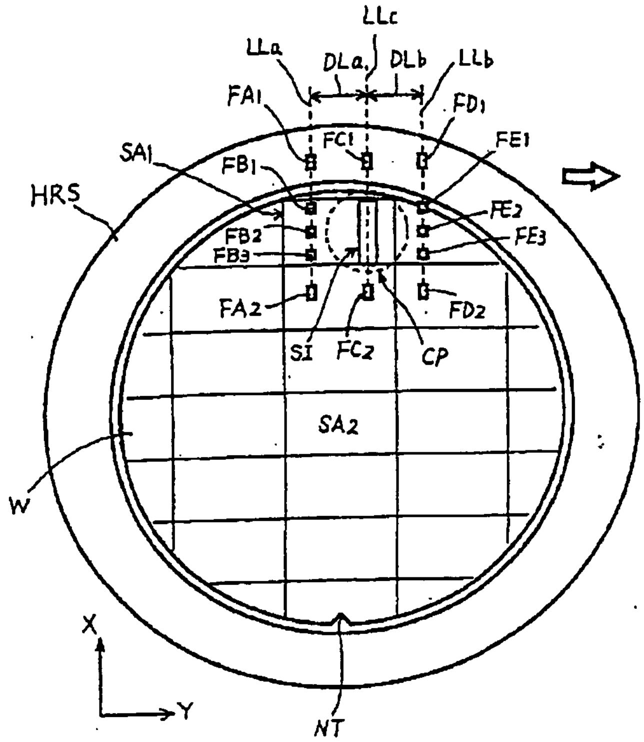
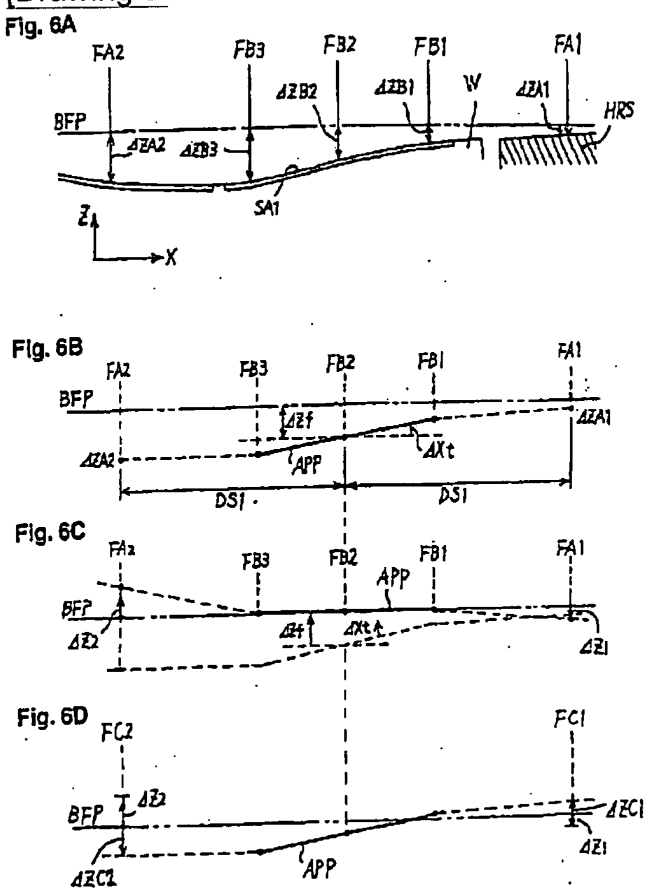


[Drawing 6

Fig. 6A



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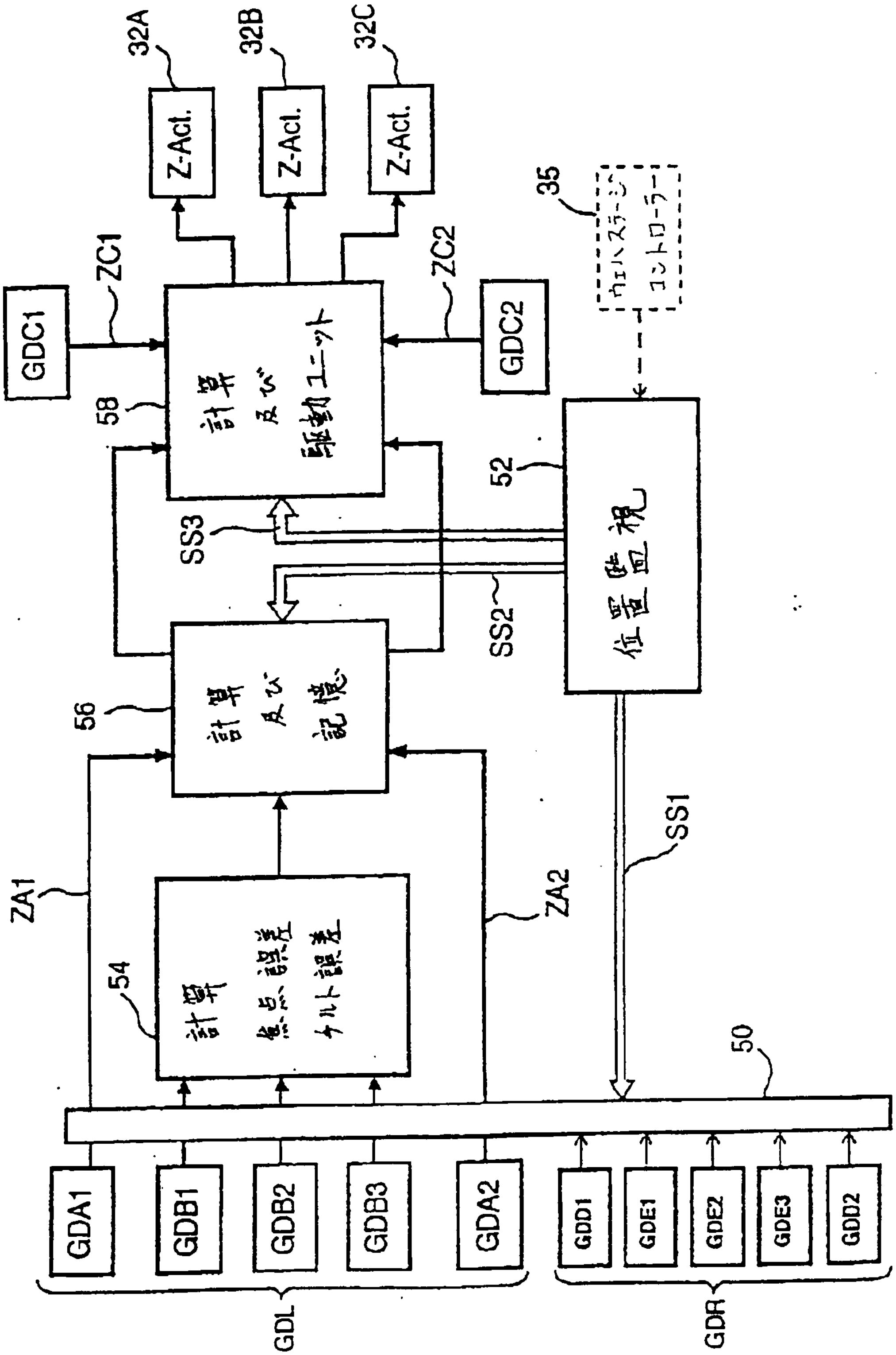
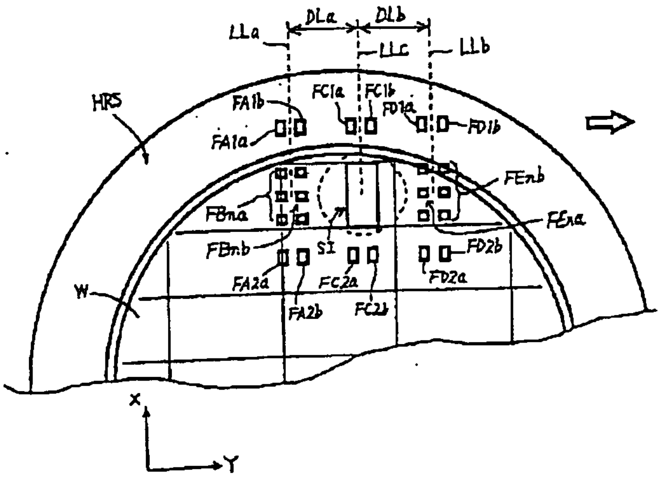
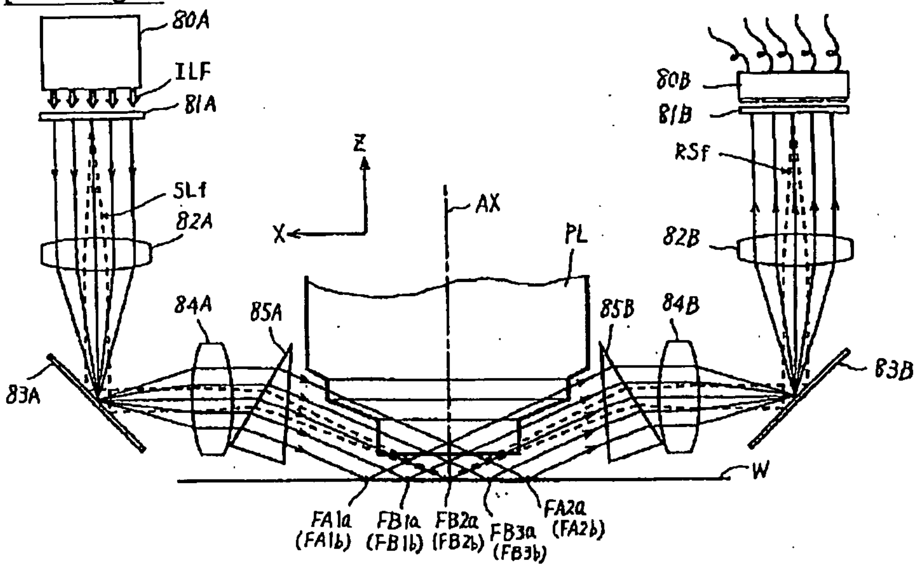

32A
32B
32C
Z-Act.
Z-Act.
Z-Act.
35
ウエハステージコントローラー
GDC1
ZC1
ZC2
GDC2
58
計算及び駆動ユニット
52
位置監視
SS3
SS2
SS1
56
計算及び記憶
ZA1
ZA2
54
計算 焦点誤差 チルト誤差
50
GDA1
GDB1
GDB2
GDB3
GDA2
GDD1
GDE1
GDE2
GDE3
GDD2
GDL
GDR

[Drawing 7



[Drawing 8



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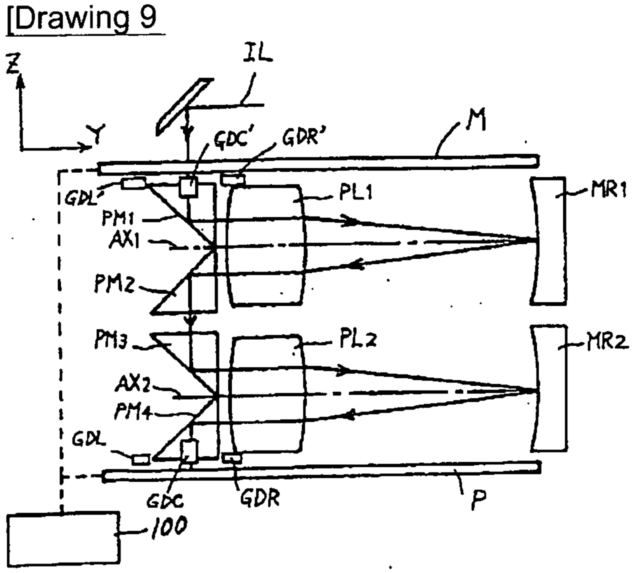

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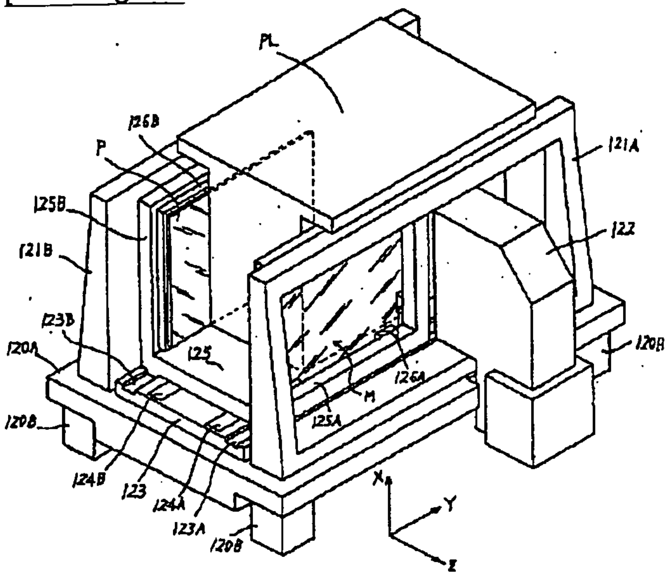

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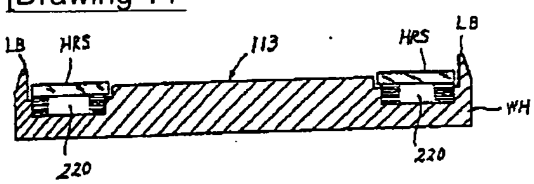
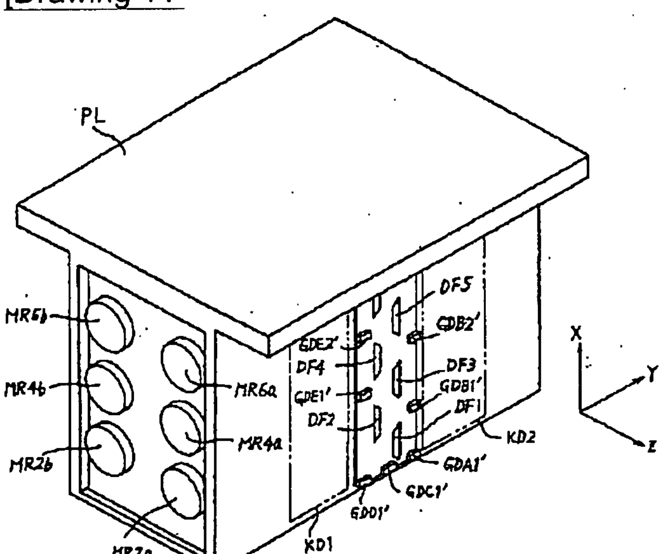


[Drawing 11



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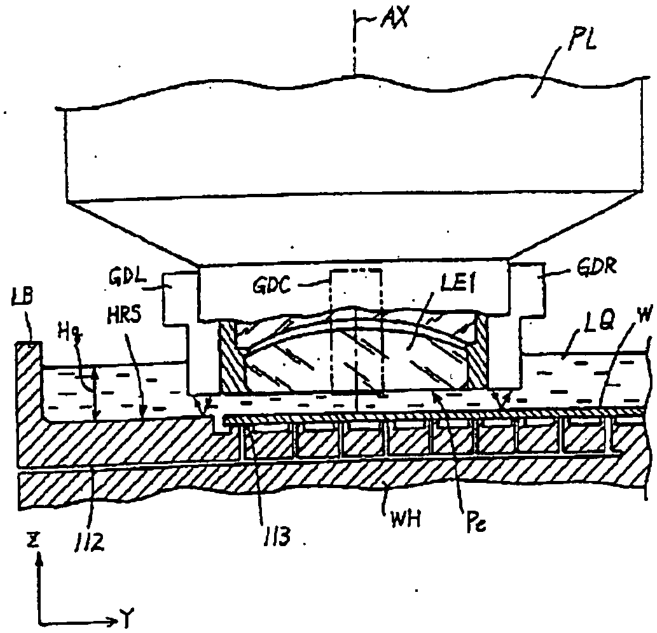
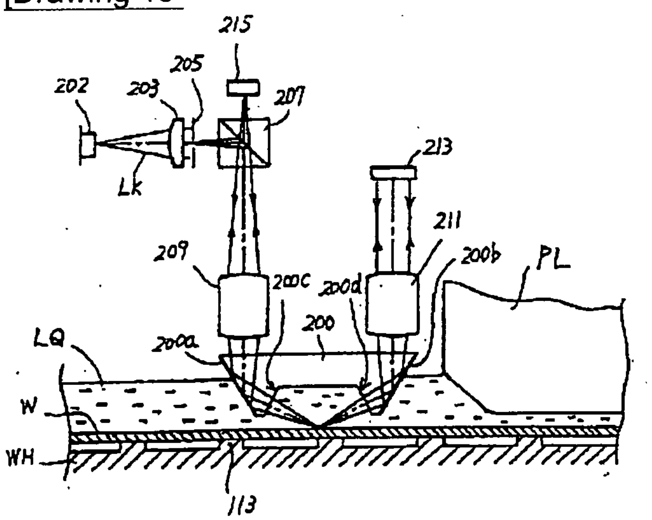
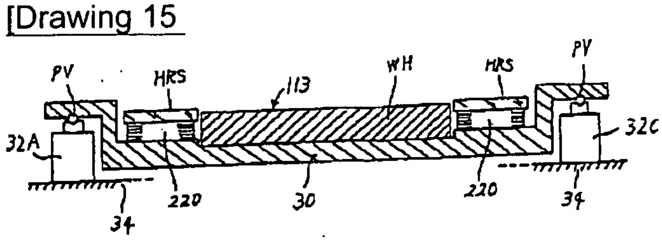


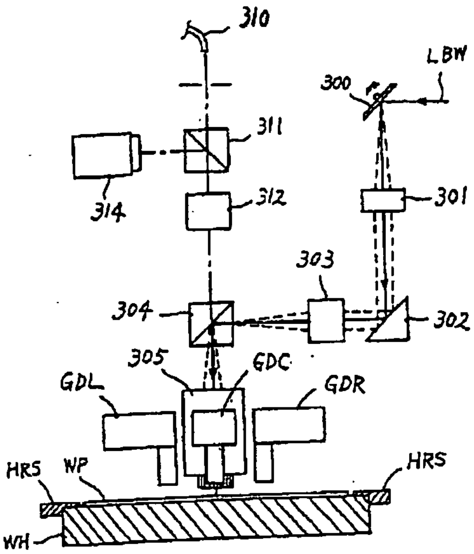
[Drawing 13



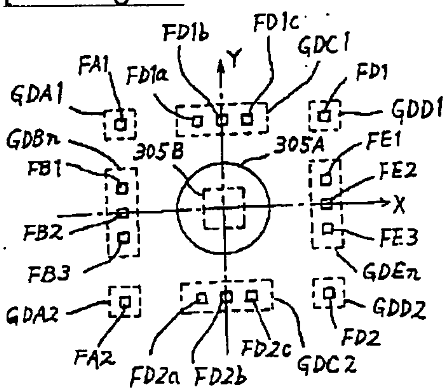
[Drawing 15



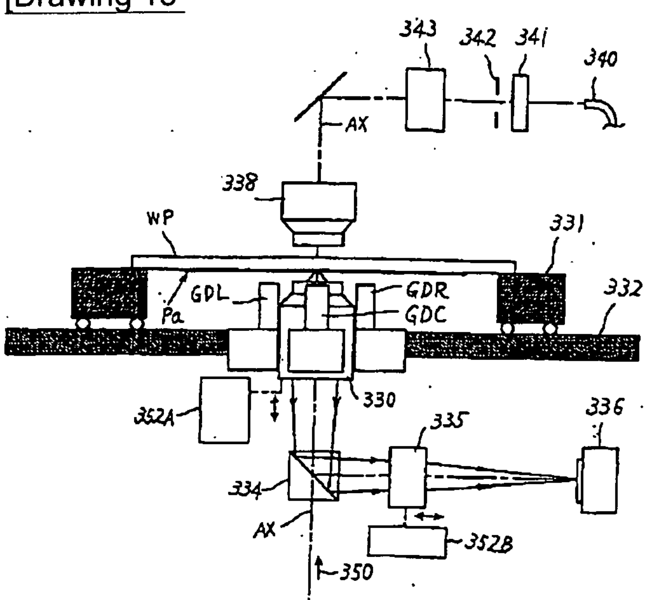
[Drawing 16



[Drawing 17



[Drawing 18



[Translation done.]

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Ｇ０３Ｆ　7/207		Ｇ０３Ｆ　7/207	Ｈ
		Ｈ０１Ｌ　21/30	５１６Ｂ
			５２６Ｂ

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(71)出願人　000004112
株式会社ニコン
東京都千代田区丸の内３丁目２番３号

(72)発明者　諏訪　恭一
東京都千代田区丸の内３丁目２番３号　株式会社ニコン内

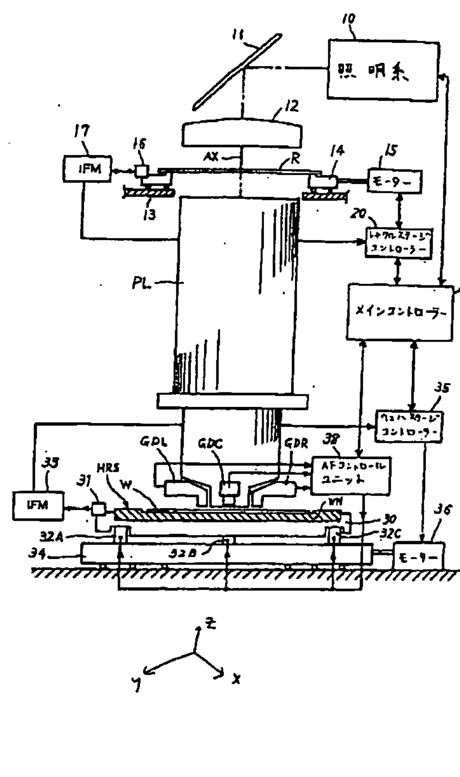
(74)代理人　弁理士　社本　一夫　（外５名）

(54)【発明の名称】リソグラフィーアライナー、製造装置、または検査装置用の焦点及びチルト調節システム

(57)【要約】　（修正有）

【課題】　通常の投影光学系と比較してワーキングディスタンスを減少させる投影光学系が組み入れられても、高精度に焦点合わせ及びチルト制御を行う。

【解決手段】　焦点合わせ装置は、第１の位置に検出領域を備えた第１の検出系、第２の位置に検出領域を備えた第２の検出系、及び第３の位置に検出領域を備えた第３の検出系を備える。第１の位置、第２の位置、第３の位置は対物レンズ光学系の視野の外側に設けられ第１、第２の位置、第３の位置は間隔があけられる。第１の焦点位置と目標焦点位置との間のずれを計算し第１の検出系による検出のときに、第２の焦点位置を一時的に記憶する。第１の検出系の検出領域に対応する被加工物上の領域が被加工物と対物レンズ光学系との相対移動によって対物レンズ光学系の視野に位置決めされたとき、コントローラが、計算されたずれと記憶された第２の焦点位置と第３の焦点位置とに基づいて焦点合わせを制御する。



【特許請求の範囲】
【請求項１】　スキャニング露光装置であって、
（ａ）マスクのパターンの像を結像視野で基板上に投影するための結像系と、
（ｂ）前記結像系に対してスキャニング方向に前記マスク及び前記基板を移動させるためのスキャニング機構と、
（ｃ）前記基板上に投影される像の焦点を調節するための調節系と、
（ｄ）第１の位置に検出領域を備えた第１の検出系とを備えており、前記第１の位置は、前記結像系の前記結像視野の外側に設けられ、前記結像視野から前記スキャニング方向に間隔をあけて設けられており、前記第１の検出系は、前記基板の表面のＺ方向の位置を検出し、
前記スキャニング露光装置は、また、
（ｅ）第２の位置に検出領域を備えた第２の検出系を備えており、前記第２の位置は、前記結像系の前記結像視野の外側に設けられ、前記第１の位置から前記スキャニング方向と交差する方向に間隔をあけて設けられており、前記第２の検出系は、前記基板の表面のＺ方向の位置を検出し、
前記スキャニング露光装置は、また、
（ｆ）第３の位置に検出領域を備えた第３の検出系を備えており、前記第３の位置は、前記結像系の前記結像視野の外側に設けられ、前記結像視野から前記スキャニング方向と交差する方向に間隔をあけて設けられており、また、前記第３の位置は、前記第２の位置から前記スキャニング方向に間隔をあけて設けられており、前記第３の検出系は、前記基板の表面のＺ方向の位置を検出し、
前記スキャニング露光装置は、また、
（ｇ）前記第１の検出系と前記第２の検出系とに連結され、前記第１の検出系によって検出された前記第１のＺ位置と目標Ｚ位置との間のずれを計算し、前記第１の検出系による検出のときに、前記第２の検出系によって検出された前記第２のＺ位置を記憶する計算器と、
（ｈ）前記調節系と前記計算器と前記第３の検出系とに連結されたコントローラとを備えており、前記第１の検出系の前記検出領域に対応する前記基板上の前記領域が、前記スキャニング機構の移動によって前記結像系の結像視野に位置したとき、前記コントローラは、前記計算されたずれと、前記記憶された第２のＺ位置と、前記第３の検出系によって検出された前記第３のＺ位置と、に基づいて前記調節系を制御することを特徴とするスキャニング露光装置。
【請求項２】　請求項１に記載のスキャニング露光装置において、
前記スキャニング機構は、前記マスクを保持するためのマスクステージと、前記基板を保持するための基板ステージと、前記結像系の投影倍率に対応する速度比で、前記マスクステージと前記基板ステージとを移動させるための同期駆動系とを備えていることを特徴とするスキャニング露光装置。
【請求項３】　請求項２に記載のスキャニング露光装置において、
前記基板ステージは、前記基板の裏面を引きつけるための吸引部と、前記基板が前記吸引部に支持されたとき、前記基板の表面とほぼ等しい高さで前記基板を囲む補助プレート部とを備えていることを特徴とするスキャニング露光装置。
【請求項４】　請求項３に記載のスキャニング露光装置において、
前記マスクのパターンによって露光される前記基板のショット領域が、前記基板の周辺部にあるときに、前記第２の検出系と前記第３の検出系は、前記検出領域のうち少なくとも１つの検出領域によって前記補助プレート部の表面のＺ方向における位置を検出できるように配置されていることを特徴とするスキャニング露光装置。
【請求項５】　請求項４に記載のスキャニング露光装置において、
前記第１の検出系は、該第１の検出系に関する所定の基準Ｚ位置に対する前記基板の表面のＺ方向位置誤差値、及び、該第１の検出系に関する所定の基準Ｚ位置に対する前記補助プレート部のＺ方向位置誤差値の一方を発生し、
前記第２の検出系は、該第２の検出系に関する所定の基準Ｚ位置に対する前記基板の表面のＺ方向位置誤差値、及び、該第２の検出系に関する所定の基準Ｚ位置に対する前記補助プレート部のＺ方向位置誤差値の一方を発生し、
前記第３の検出系は、該第３の検出系に関する所定の基準Ｚ位置に対する前記基板の表面のＺ方向位置誤差値、及び、該第３の検出系に関する所定の基準Ｚ位置に対する前記補助プレート部のＺ方向位置誤差値の一方を発生することを特徴とするスキャニング露光装置。
【請求項６】　請求項５に記載のスキャニング露光装置において、
前記第１の検出系に関する前記所定の基準Ｚ位置と、前記第２の検出系に関する前記所定の基準Ｚ位置と、前記第３の検出系とに関する前記所定の基準Ｚ位置とが、互いに異なっている場合に、
前記所定の基準Ｚ位置の間の差異が、較正によって検出されることを特徴とするスキャニング露光装置。
【請求項７】　請求項４に記載のスキャニング露光装置において、
前記基板のスキャニング方向がＹ方向である場合で、また、前記Ｙ方向及び前記Ｚ方向の各々に直交する方向がＸ方向である場合に、前記第１の検出系は、複数の検出領域を有するマルチポイントタイプの第１の焦点検出器を備えており、前記複数の検出領域は、前記結像系の結像視野の前記Ｘ方向におけるサイズの範囲にわたって、

前記基板上で、前記Ｘ方向に沿って一列になっていることを特徴とするスキャニング露光装置。

【請求項８】　請求項７に記載のスキャニング露光装置において、

前記第２の検出系は、複数の第２の焦点検出器を備えており、前記第２焦点検出器は、前記マルチポイントタイプの第１の焦点検出器の、一列となっている前記複数の検出領域のうち前記Ｘ方向における両側に検出領域を備えており、前記第２の焦点検出器の各々は、前記検出領域の各々で、前記基板及び前記補助プレート部の一方の前記表面のＺ方向位置を個々に検出することを特徴とするスキャニング露光装置。

【請求項９】　請求項８に記載のスキャニング露光装置において、

前記第３の検出系は、複数の第３の焦点検出器を備えており、前記第３焦点検出器は、前記投影系の前記結像視野の前記Ｘ方向における両側に設けられており、前記第３の焦点検出器の各々は、前記検出領域の各々で、前記基板及び前記補助プレート部の一方の前記表面のＺ方向位置を個々に検出することを特徴とするスキャニング露光装置。

【請求項１０】　投影露光装置であって、

（ａ）マスクパターンの像を投影視野で基板に投影するための結像系と、

（ｂ）Ｘ方向及びＹ方向に交差する方向に移動して、前記投影されたマスクパターンの像に関して前記基板を位置決めするための可動ステージ機構と、

（ｃ）前記基板上に投影されるマスクパターンの像の焦点を調節するための調節機構と、

（ｄ）第１の位置に検出領域を備えた第１の検出系とを備えており、前記第１の位置は、前記結像系の前記投影視野の外側に設けられ、前記投影視野から前記Ｙ方向に間隔をあけて設けられており、前記第１の検出系は、前記基板の表面のＺ方向の位置を検出しており、

前記投影露光装置は、また、

（ｅ）第２の位置に検出領域を備えた第２の検出系を備えており、前記第２の位置は、前記結像系の前記投影視野の外側に設けられ、前記第１の位置から前記Ｘ方向に間隔をあけて設けられており、前記第２の検出系は、前記基板の表面のＺ方向の位置を検出しており、

前記投影露光装置は、また、

（ｆ）第３の位置に検出領域を備えた第３の検出系を備えており、前記第３の位置は、前記結像系の前記投影視野の外側に設けられ、前記投影視野から前記Ｘ方向に間隔をあけて設けられており、また、前記第３の位置は、前記第２の位置から前記Ｙ方向に間隔をあけて設けられており、前記第３の検出系は、前記基板の表面のＺ方向の位置を検出しており、

前記投影露光装置は、また、

（ｇ）前記第１の検出系と前記第２の検出系とに連結され、前記第１の検出系によって検出された前記第１のＺ位置と目標Ｚ位置との間のずれを計算し、前記第１の検出系による検出のときに、前記第２の検出系によって検出された前記第２のＺ位置を記憶するための計算器と、

（ｈ）前記調節機構と前記計算器と前記第３の検出系とに連結されたコントローラとを備えており、前記第１の検出系の前記検出領域に対応する前記基板上の前記領域が、前記可動ステージ機構によって前記結像系の前記投影視野に位置するときに、前記コントローラは、前記計算されたずれと、前記記憶された第２のＺ位置と、前記第３の検出系によって検出された前記第３のＺ位置と、に基づいて前記調節機構を制御することを特徴とする投影露光装置。

【請求項１１】　請求項１０に記載の投影露光装置において、

前記第１の検出系は、複数の検出領域を有する複数の第１の焦点検出器を備えており、前記複数の検出領域は、前記結像系の投影視野の前記Ｘ方向におけるサイズに応じた範囲で、前記Ｘ方向に沿って一列になっており、前記第１の焦点検出器の各々は、前記検出領域の各々で、前記基板の表面のＺ位置を個々に検出することを特徴とする投影露光装置。

【請求項１２】　請求項１１に記載の投影露光装置において、

前記第２の検出系は、２つの第２の焦点検出器を備えており、前記２つの第２の焦点検出器は、前記第１の検出系の、一列となっている前記複数の検出領域の両側に配置された２つの検出領域を備えており、前記第２の焦点検出器の各々は、前記２つの検出領域の各々で、前記基板の表面のＺ位置を個々に検出することを特徴とする投影露光装置。

【請求項１３】　請求項１２に記載の投影露光装置において、

前記第３の検出系は、２つの第３の焦点検出器を備えており、前記２つの第３の焦点検出器は、前記結像系の前記投影視野の前記Ｘ方向における両側に配置されており、前記第３の焦点検出器の各々は、前記２つの検出領域の各々で、前記基板の表面のＺ位置を個々に検出することを特徴とする投影露光装置。

【請求項１４】　請求項１３に記載の投影露光装置において、

前記可動ステージ機構は、前記基板の裏面を引きつけるための取付部と、前記基板が前記取付部に支持されたとき、前記基板の表面と実質的に等しい高さで前記基板を囲む補助プレート部とを備えており、前記補助プレート部の表面は、前記２つの第２の焦点検出器のうちの１つと、前記２つの第３の焦点検出器のうちの１つとによって検出されることを特徴とする投影露光装置。

【請求項１５】　投影系を通してマスクのパターンの一部を感光性基板に投影し、前記投影系の投影視野に対し

て前記マスクと前記感光性基板とを移動させることによって、前記マスクのパターンを前記感光性基板に転写するスキャニング露光方法であって、前記方法は、
（ａ）前記感光性基板の表面の高さと実質的に等しい高さで前記感光性基板を囲む補助プレート部を有するホルダーに、前記感光性基板を取り付けるステップと、
（ｂ）前記マスクパターンの一部が投影される前記感光性基板の露光領域の焦点誤差を読み取るステップとを備えており、前記ホルダーと前記感光性基板とをスキャニング移動させる間で、前記露光領域が前記投影系の投影視野に達する前に、前記露光領域の前記焦点誤差が読み取られるようになっており、
前記方法は、また、
（ｃ）前記感光性基板上の露光領域が前記投影視野に達するときに、前記スキャニング移動方向に直交する方向に前記投影系の投影視野から離れて配置された露光位置用の焦点検出系によって、前記感光性基板及び前記補助プレート部の一方の一部の表面の焦点誤差を検出するステップと、
（ｄ）前記ステップ（ｂ）及び（ｃ）によって検出された前記焦点誤差に基づいて、前記投影系と前記感光性基板との間で焦点を調節するステップとを備えており、それによって、前記感光性基板上での露光領域の焦点誤差が、前記投影系の投影視野で補正されることを特徴とするスキャニング露光方法。
【請求項１６】　請求項１５に記載のスキャニング露光方法において、
前記方法は投影アライナーに適用されており、前記投影アライナーは投影系を有しており、前記投影系は、前記基板の表面に対して２０ｍｍまたはそれ以下の有効作動距離を備えていることを特徴とするスキャニング露光方法。
【請求項１７】　請求項１５に記載のスキャニング露光方法において、
前記方法は、液浸式の投影露光装置に適用されており、前記液浸式の投影露光装置において、前記感光性基板と、前記投影光学系の像面側に配置された透明な光学素子との間で、投影光路を含む空間が、液体で満たされていることを特徴とするスキャニング露光方法。
【請求項１８】　請求項１７に記載のスキャニング露光方法において、
前記投影光学系は、前記感光性基板と前記投影光学系の前記透明な光学素子との間の液体の厚さが２ｍｍまたはそれ以下となるような作動距離を備えていることを特徴とするスキャニング露光方法。
【請求項１９】　請求項１５に記載のスキャニング露光方法において、
前記方法は、スキャニング露光装置に適用されており、前記スキャニング露光装置は、反射屈折投影系を有しており、前記反射屈折投影系は、屈折用の光学素子と反射用の光学素子とを有しており、前記スキャニング露光装置において、透明な光学素子が像面側に配置されていることを特徴とするスキャニング露光方法。
【請求項２０】　請求項１９に記載のスキャニング露光方法において、
前記像面側に配置された前記透明な光学素子は、プリズムミラーとなっており、前記プリズムミラーは、前記感光性基板の表面に実質的に平行な射出表面を備えていることを特徴とするスキャニング露光方法。
【請求項２１】　被加工物の表面と対物レンズ光学系との間で焦点合わせを制御できるように、前記対物レンズ光学系を有する装置に設けられた焦点合わせ装置であって、前記焦点合わせ装置は、
（ａ）第１の位置に検出領域を備えた第１の検出系を備えており、前記第１の位置は、前記対物レンズ光学系の視野の外側に設けられており、前記第１の検出系は、前記被加工物の表面の前記焦点合わせ方向の位置を検出しており、
前記焦点合わせ装置は、また、
（ｂ）第２の位置に検出領域を備えた第２の検出系を備えており、前記第２の位置は、前記対物レンズ光学系の視野の外側に設けられ、前記第１の位置から間隔をあけて設けられており、前記第２の検出系は、前記被加工物の表面の前記焦点合わせ方向の位置を検出しており、
前記焦点合わせ装置は、また、
（ｃ）第３の位置に検出領域を備えた第３の検出系を備えており、前記第３の位置は、前記対物レンズ光学系の視野の外側に設けられ、前記第１の位置及び前記第２の位置の各々から間隔をあけて設けられており、前記第３の検出系は、前記被加工物の表面の前記焦点合わせ方向の位置を検出しており、
前記焦点合わせ装置は、また、
（ｄ）前記第１の検出系と前記第２の検出系とに連結され、前記第１の検出系によって検出された前記第１の焦点位置と目標焦点位置との間のずれを計算し、前記第１の検出系による検出のときに、前記第２の検出系によって検出された前記第２の焦点位置を記憶するための計算器と、
（ｅ）前記計算器と前記第３の検出系とに連結されたコントローラとを備えており、前記第１の検出系の前記検出領域に対応する前記被加工物上の前記領域が、前記被加工物と前記対物レンズ光学系との相対移動によって前記対物レンズ光学系の視野に位置決めするとき、前記コントローラは、前記計算されたずれと、前記記憶された第２の焦点位置と、前記第３の検出系によって検出された前記第３の焦点位置と、に基づいて、前記被加工物の前記表面上での前記対物レンズ光学系の焦点合わせを制御することを特徴とする焦点合わせ装置。
【請求項２２】　被加工物と対物レンズ光学系の視野とがＸ方向とＹ方向に互いに対して移動するとき、前記被

加工物の表面での前記対物レンズ光学系の焦点合わせを制御する方法であって、前記方法は、
（ａ）前記被加工物の表面の高さと実質的に等しい高さで前記被加工物を囲む補助プレート部を有するホルダーに前記被加工物を取り付けるステップと、
（ｂ）前記ホルダーと前記被加工物とを所定の移動方向に移動させる間で、前記被加工物の所定の局部的な部分が前記対物レンズ光学系の視野に達する前に、前記被加工物の表面の前記局部的な部分の焦点誤差を読み取るステップとを備えており、
前記方法は、また、
（ｃ）前記被加工物の前記局部的な部分が前記視野に達するときに、前記移動方向に直交する方向に前記対物レンズ光学系の視野から離れて配置された第１の焦点検出系によって、前記被加工物及び前記補助プレート部の一方の一部の表面の焦点誤差を検出するステップと、
（ｄ）前記ステップ（ｂ）及び（ｃ）によって検出された前記焦点誤差に基づいて、前記対物レンズ光学系と前記被加工物との間で焦点合わせを制御し、それによって、前記被加工物の局部的な部分の焦点誤差が、前記対物レンズ光学系の視野で補正されることを特徴とする方法。
【請求項２３】　請求項２２に記載の方法において、前記方法は、斜入射光タイプの焦点検出器の検出ビームが前記対物レンズ光学系の真下で前記被加工物の表面に斜めに導かれないようにわずかな有効作動距離を有する、製造用の計測器、リソグラフィー露光装置、描画装置、及び検査装置の少なくとも１つに適用されることを特徴とする方法。
【請求項２４】　光学的な結像系と、該光学的な結像系と感光性基板との間の空間にある液体とを通して、マスクパターン像を感光性基板に投影するための投影露光装置であって、前記投影露光装置は、
前記結像系の複数の光学素子を保持するアセンブリを備えており、前記アセンブリの少なくとも一端部が前記液体に浸されており、
前記投影露光装置は、また、
前記アセンブリの前記端部に取り付けられ、前記基板に対向し前記液体に接触する末端表面を有する末端光学素子を備えており、
前記末端光学素子の前記末端表面と、前記アセンブリの前記端部の表面とが、互いに対して実質的に同一平面となっており、それによって、前記液体の流れの妨害を阻止することを特徴とする投影露光装置。
【請求項２５】　投影系を採用し、半導体ウェハに成型部を加工する方法であって、
（ａ）前記半導体ウェハをホルダーに取り付けるステップを備えており、前記ホルダーは、周辺部に垂直に設けられた壁部を備えており、これにより、前記ウェハの表面と前記投影系との間が液浸状態となるように前記ウェハ上に液体層を形成することができ、
前記方法は、また、
（ｂ）前記投影系の像面に沿って前記ホルダーをスキャニングし、これにより、前記投影系と前記液体層とを通して前記ウェハに成型部パターン像を投影することによってスキャン露光を行うスキャニングステップと、
（ｃ）焦点検出系を使用することによって、前記ウェハの表面と前記投影系の像面との間の焦点誤差及びチルト誤差のうちの少なくとも一方を前記スキャニングステップの間に補正するステップとを備えており、前記焦点検出系は、前記投影系の像面の外側に配置された複数の焦点検出ポイントを備えていることを特徴とする方法。
【請求項２６】　請求項２５に記載の方法において、前記投影系は、０．５マイクロメートルよりも小さい解像度を備えていることを特徴とする方法。
【請求項２７】　マスクのパターンを結像系を通して基板に転写するためのスキャニング露光方法であって、前記スキャニング露光方法は、
第１の検出領域を備えた第１の検出系を提供するステップを備えており、前記第１の検出領域は、前記結像系の結像視野の外側に設けられていると共に、前記結像視野からスキャニング方向に間隔をあけて設けられており、前記第１の検出系は、前記基板の表面の、前記結像系の光軸方向における位置を検出しており、
前記スキャニング露光方法は、また、
第２の検出領域を備えた第２の検出系を提供するステップを備えており、前記第２の検出領域は、前記結像系の結像視野の外側に設けられていると共に、前記第１の検出領域から前記スキャニング方向と交差する方向に間隔をあけて設けられており、前記第２の検出系は、前記基板の表面の前記光軸方向における位置を検出しており、
前記スキャニング露光方法は、また、
第３の検出領域を備えた第３の検出系を提供するステップを備えており、前記第３の検出領域は、前記結像系の結像視野の外側に設けられていると共に、前記結像視野から前記スキャニング方向と交差する方向に間隔をあけて設けられ、さらに、前記第２の検出領域から前記スキャニング方向に間隔をあけて設けられており、前記第３の検出系は、前記基板の表面の位置と目標位置との間の、前記光軸方向におけるずれを検出しており、
前記スキャニング露光方法は、また、
前記基板の露光の間に、前記第１の検出系の検出結果と前記第２の検出系の検出結果とに基づいて、前記第３の検出系の目標位置を決定するステップと、
前記基板の露光の間に、前記第１の検出系の検出結果と前記第２の検出系の検出結果と前記第３の検出系の検出結果とに基づいて、前記基板の表面と前記結像系の像面との間の位置関係を調節するステップとを備えていることを特徴とするスキャニング露光方法。
【発明の詳細な説明】

【０００１】
【発明の属する技術分野】本願発明は、半導体の製造に関し、特に、回路パターンを、マスクまたはレチクルから感光基板に転写するためのリソグラフィー露光装置（アライナー）に関する。
【０００２】本願発明は、また、被加工物、すなわちワークピース（ウェハ、基板、またはプレートなど）上の焦点を検出するための、また、前記被加工物のチルト（すなわち、傾斜）を検出するためのシステム（系）に関する。当該システムは、レーザーや電子ビームを使用して、被加工物を製造しまたは被加工物の表面に所望のパターンを結像するための装置や被加工物の表面の状態を光学的に検査するための装置のようなある種類の装置に適用できる。
【０００３】
【従来の技術】近年、集積密度６４メガビットを有するダイナミイック・ランダム・アクセス・メモリの半導体チップ（ＤＲＡＭｓ）が、半導体製造技術によって大量生産されている。そのような半導体チップは、半導体ウェハを露光して回路パターンを結像し、これによって、例えば、１０層あるいはそれ以上の層の回路パターンを重ね合わせ形成することによって、製造されている。
【０００４】一方、現在、そのようなチップの製造に使用されるリソグラフィー装置は、投影用のアライナーである。その投影用のアライナーにおいては、レチクル（または、マスクプレート）上のクロム層に描かれた回路パターンが、水銀灯のｉ線（波長３６５ｎｍ）やＫｒＦエキシマーレーザーからの２４８ｎｍの波長を有するパルス光で、前記レチクルを照射することによって、４分の１または5分の１に縮小する縮小光学結像系（すなわち、縮小投影光学系）を通して、ウェハ表面のレジスト層に転写される。
【０００５】この目的のために使用される投影露光装置（投影用のアライナー）は、結像光学系のタイプに応じて、ステップアンドリピート方式を利用するもの（すなわち、いわゆるステッパー）と、最近注目を受けているステップアンドスキャン方式を利用したものとに概ねグループ分けされている。
【０００６】ステップアンドリピート方式においては、工程が繰り返される。すなわち、その工程においては、ウェハがステッピング方法である程度移動するごとに、レチクルのパターン像が、縮小投影レンズ系または単一の倍率の投影レンズ系を使用することによって、ウェハの一部に投影される。前記縮小投影レンズ系は、屈折用の光学材料（レンズ素子）のみから形成されており、円形の像視野を備えている。単一の倍率の投影レンズ系は、屈折用の光学材料（レンズ素子）、プリズムミラー、及び凹面鏡から形成されており、非円形の像視野を備えている。前記像視野によって、ウェハやプレートのショット領域がパターン像に露出される。
【０００７】スッテプアンドスキャン方式においては、ウェハは、（例えば、円弧状のスリットの形状の）レチクルの回路パターンの一部の像に露光される。レチクルの回路パターンの一部の像は、投影光学系を通ってウェハに投影される。同時に、レチクルとウェハは、連続的に、一定の速度で且つ投影倍率に応じた速度比で移動する。したがって、スキャニング方法では、ウェハ上の１つのショット領域が、レチクル上の全回路パターンの像に露光される。
【０００８】例えば、「オプティカル／レーザー・マイクロリソグラフィー（Ｏｐｔｉｃａｌ／Ｌａｓｅｒ Ｍｉｃｒｏｌｉｔｈｏｇｒａｐｈｙ）（１９８８）のＳＰＩＥＶｏｌ．９２２の２５６ページないし２６９ページに記述されているように、スッテプアンドスキャン方式は、ウェハ上の１つのショット領域がスキャンされ露光された後、ウェハは１ステップ移動し、隣のショット領域が露光されるように構成され、また、投影光学系の有効像視野が円弧状のスリットに制限されるように構成されている。また、投影光学系は、（Ｓｈａｆｅｒに付与された）米国特許第４，７４７，６７８に開示されているもののように、複数の屈折用の光学要素と、複数の反射用の光学要素との組み合わせと考えることができる。
【０００９】（Ｎｉｓｈｉに付与された）米国特許は、アライナーの一例を開示している。このアライナーにおいては、スッテプアンドスキャン方式が、円形の像視野を有するステッパー用の縮小投影レンズを取り付けることによって、実行されている。この米国公報は、また、スキャニング露光のときに投影されるパターン像が、所定量だけウェハ上の焦点深度（ＤＯＦ）を増加させることによって、ウェハに転写される方法を開示している。
【００１０】リソグラフィー技術の分野においては、光りによる露光により、１ギガまたは４ギガ程度の集積密度及び精度を有する半導体メモリチップを製造できることが望ましい。光りにより露光する技術は長い技術的歴史を有しており、大量に蓄積されたノウハウに基づいていることから、光りにより露光する技術を継続して使用することが便利である。また、他の代わりの電子ビームによる露光技術やＸ線技術の問題点を考慮すると、光りにより露光する技術を使用することが効果的である。
【００１１】１ギガのメモリチップに関しては、最小のライン幅（形状幅）を、約０．１８μｍ（マイクロメートル）にする必要があると考えられている。一方、４ギガのメモリチップに関しては、最小のライン幅（形状幅）を、約０．１３μｍ（マイクロメートル）にする必要があると考えられている。そのようなライン幅を達成するためには、２００ｎｍあるいはそれより短い波長を有する遠紫外線、例えば、ＡｒＦエキシマーレーザーによって生じる遠紫外線が使用され、これにより、レチクルパターンを照射することができる。
【００１２】（４００ｎｍまたはそれより短い波長を有

する）遠紫外線に対して適当な透過度を有するガラス質の光学材料として、石英（S_iO_2）、蛍石（C_aF_2）、リチウムフルオリド（L_iF_2）、マグネシウムフルオリド（M_gF_2）などが、一般的に知られている。石英と蛍石は、遠紫外線のレンジにおいて高い解像度を有する投影光学系を形成するために必要なガラス質の光学材料となっている。

【0013】しかしながら、もし、視野のサイズを増加させながら、投影光学系の開口数（ＮＡ）を増加させて高解像度を達成するならば、石英または蛍石で形成されたレンズ素子の直径が大きくなり、その結果、そのようなレンズ素子の製造が困難になるという事実を考慮することが必要である。

【0014】また、もし、投影光学系の開口数（ＮＡ）を増加させるならば、焦点深度（ＤＯＦ）ΔＦは、必然的に減少する。レイリーの結像の理論が適用されるならば、一般的に、焦点深度ΔＦは、下記に示されているように、波長、開口数ＮＡ、及びプロセス係数Ｋｆ（$0<Kf<1$）によって定義される。

【0015】$\Delta F = Kf \cdot (\lambda / NA^2)$

したがって、もし、波長が１９３ｎｍならば、すなわち、波長がＡｒＦエキシマーレーザー光の波長に等しく、開口数ＮＡが約０．７５に設定され、プロセス係数Ｋｆが０．７であるならば、大気（空気）中の焦点深度ΔＦは、約０．２４０μｍとなる。この場合、理論上の解像度（最小ライン幅）ΔＲは、プロセス係数Ｋｒ（$0<Kr<1$）を使用する下記等式によって表現される。

【0016】$\Delta R = Kr \cdot (\lambda / NA)$

したがって、上述した状態の下では、プロセス係数Ｋｒが０．６ならば、解像度ΔＲは約０．１５４μｍとなる。

【0017】上述したように、解像度を改善するために、投影光学系の開口数を増加させる必要がある一方で、もし、開口数が増加するならば、焦点深度が急激に減少することに注意することが重要である。もし、焦点深度が小さいならば、精度、再現精度、及び安定性を改善する必要がある。精度、再現精度、及び安定性に基づいて、投影光学系の最良の像面とウェハ上のレジスト層面との間を合わせるための自動焦点合わせ系が、制御される。

【0018】他方、デザインや製造の見地から投影光学系を考慮すると、視野のサイズを増加させることなしに、開口数を増加させる構成が可能である。しかしながら、もし、開口数を実質的に大きな値に設定するならば、レンズ素子の直径が大きくなり、その結果、ガラス質の光学材料（例えば、石英や蛍石）を形成し加工することが困難となる。

【0019】次いで、投影光学系の開口数を大きく増加させることなしに解像度を改善するための手段として、液浸投影方法を使用してもよい。この方法においては、ウェハと投影光学系との間のスペースに、液体が充填されている。これに関しては、（Ｔａｂａｒｅｌｌｉに付与された）米国特許第４，３４６，１６４を参照されたい。

【0020】この液浸投影方法においては、ウェハと、投影光学系を投影端側（像面側）で構成する光学要素との間の空間に、フォトレジスト層の屈折率に近い屈折率を有する液体が充填されている。これにより、ウェハ側からみた投影光学系の有効開口数が増加し、すなわち、解像度を改善することができる。この液浸投影方法は、使用する液体を選択することによって、良好な結像性能を獲得できると期待されている。

【0021】現在公知な投影アライナーには、一般的に、自動焦点合わせ（ＡＦ）系が設けられている。この自動焦点合わせ系は、ウェハと投影光学系との相対位置を正確に制御し、それによって、ウェハの表面を、投影光学系の最適な像面（レチクルの共役面）に合致させることができる。この自動焦点合わせ系は、ウェハ表面の高さ方向の位置（Ｚ方向位置）の変化を非接触で検出するための表面位置検出センサと、この検出された変化に基づいて、投影光学系とウェハとの間の間隔を調節するためのＺ方向調節機構とを備えている。

【0022】また、現在使用されている投影アライナーにおいては、また、光学タイプのセンサや空気マイクロメータータイプのセンサが、表面位置検出センサとして使用されている。また、ウェハを支持するためのホルダー（及びＺステージ）が、Ｚ方向調節機構として設けられている。ウェハを支持するホルダー（及びＺステージ）は、サブミクロン精度で垂直方向に移動する。

【0023】もし、そのような自動焦点合わせ系が、液浸投影方法が適用されるアライナーに設けられるならば、ウェハが液体に保持されることから、空気マイクロメータータイプのセンサを使用することができず、光学式のセンサが独占的に使用されるのが自然である。そのような場合、例えば、（Ｓｕｗａに付与された）米国特許第４，６５０，９８３に開示されたような焦点合わせ用の光学式センサが構成される。それによって、測定用のビーム（スリット像の結像ビーム）が、ウェハ上の投影視野に斜めに投影され、また、ウェハ表面で反射された測定用のビームが、受光用のスリットを通して、光電式の検出器によって受光される。ウェハ表面の高さの変化、すなわち、焦点誤差量が、受光用のスリットで起きる反射されたビーム（反射ビーム）の位置の変化から検出される。

【0024】米国特許第４，６５０，９８３に開示されたような斜入射光（斜めに光りを入射する）タイプの焦点合わせ用のセンサが、１０ないし２０ｎｍの作動距離を有する通常の投影光学系が液体に浸されている投影アライナーに直接的に取り付けられているならば、下記に述べる問題が生じる。そのような場合、下記のような投

影ビームと反射ビームとが通る投影光学系を液体に設定する必要がある。すなわち、その投影ビームは、焦点合わせ用のセンサの投影用対物レンズから放射されて、ウェハ上にある投影光学系の投影視野に到達する。その反射ビームは、ウェハによって反射されて、受光用の対物レンズに到達する。

【0025】そのため、焦点合わせ用のセンサのビームは、液体中を長い距離にわたって進む。それによって、液体の温度分布が高精度に安定していないならば、投影ビームや受光されたビームは、温度が不均等になっているので、屈折率の変化によって変動し、その結果、焦点検出（すなわち、ウェハ表面の高さ方向の位置の検出）の精度が低下することとなる。

【0026】さらに、液浸投影方法によって、０．１５λｍまたはそれ以下の解像度を達成するために、上述したように、投影光学系の作動距離を十分に小さい値に設定する必要がある。そのため、斜入射光（斜めに光りを入射する）タイプの焦点合わせ用のセンサの投影ビームそれ自身を、投影光学系とウェハとの間の空間からウェハ上の投影領域に向けて斜めに投影することは、困難となる、この理由のため、液浸投影方法に適用可能な自動焦点合わせ系をどのように構成したらよいかということに関して、１つの重要な疑問が生じる。

【0027】他方、単一の倍率タイプの（以下、”１Ｘ”と言う）投影光学系を有するアライナー（露光装置）は、半導体装置を製造する分野と共に、液晶ディスプレイ装置（平坦なパネルディスプレイ）を製造する分野で使用されている。最近、この種のアライナーのために、１つのシステム（系）が提案されている。そのシステムには、あるタイプの複数の１Ｘ投影光学系が配置され、そして、マスク及び感光性のプレートが互いに対して一体的に移動してスキャニングを行うことができるようになっている。使用される１Ｘ投影光学系の作動距離は、理想的には極端に小さくなっていることが望ましい。各１Ｘ投影光学系は、（Ｈｅｒｓｈｅｌに付与された）米国特許第４，３９１，４９４号に開示されたようなシングル・ダイソン（ｓｉｎｇｌｅ　Ｄｙｓｏｎ）タイプ、または、（Ｓｗａｎｓｏｎなどに付与された）米国特許第５，２９８，９３９に開示されたようなダブル・ダイソン（ｄｏｕｂｌｅ　Ｄｙｓｏｎ）タイプとなっている。

【0028】そのようなＤｙｓｏｎ（ダイソン）タイプの投影光学系を有するアライナーにおいては、作動距離（すなわち、プリズムミラーの出口表面と像面との間の間隔）を十分に減少させることにより、投影された像の種々の収差やディストーションを小さな値に制限でき、その結果、収差やディストーションにより生じる問題が事実上なくなる。そのため、この種のアライナーにおいて、焦点合わせ用のセンサによって焦点が検出される、感光性の基板上の検出領域（例えば、光りを斜めに入射する斜入射光系における投影ビームの照射位置、または、空気マイクロメーター系における空気排出位置）は、通常、投影光学系の有効投影視野領域からそれた位置に設定される。すなわち、オフアクシス方式で設定される。

【0029】

【発明が解決しようとする課題】この理由のため、回路パターンからの投影光に露光される基板の領域が最良の焦点位置または状態に正確に調節されたかどうかを実際に検出することは不可能である。

【0030】また、基板にパターンを描画する装置においては、または、レーザービームや電子ビームのスポットを使用することによって加工（または製造）を行う装置においては、基板と、レーザービームや電子ビームを投影するための対物レンズ系（または、電子レンズ系）と、の間の作動距離が大変小さくなる。その結果、加工位置の焦点誤差を検出でき、または、対物レンズ光学系の視野における基板表面上での描画位置の焦点誤差を検出できるＡＦセンサを取り付けることができなくなる可能性が生じる。

【0031】そのような場合、ＡＦセンサの検出位置は、焦点誤差を検出するために、対物レンズ系の視野の外側にのみ置かれる。そのため、対物レンズ系の視野における加工位置または描画位置で、焦点誤差が実際に起きているかどうか検出できなくなる。

【0032】これと同じことが、フォトリソグラフィーでレチクルやマスクに描かれたパターンやウェハに形成された微細のパターンを光学的に検査するための装置に関しても言うことができる。すなわち、この種の検査装置にも、検査のための対物レンズ系が設けられているからである。また、対物レンズ系の端部は、検査される標本（プレート）の表面に向いて、所定の作動距離だけ前記標本の表面から離れて設けられているからである。

【0033】したがって、比較的に大きな倍率と高解像度とを有する対物レンズ系を使用するならば、作動距離が大変小さくなり、その結果、ＡＦセンサの性質に関する同じ問題が生じる。

【0034】

【課題を解決するための手段】関連技術の上記問題を考慮して、本願発明は、通常の投影光学系と比較して作動距離を減少させる投影光学系が組み入れられたとしても、高精度に焦点合わせの制御ができ、また、高精度にチルト制御ができる、投影アライナー（露光装置）及び露光方法を提供するものである。

【0035】本願発明は、ステップアンドリピート式のアライナーに関連している。ステップアンドリピート式のアライナーにおいては、感光性基板の表面が、投影系またはスキャニング露光装置（スキャニングアライナー）を通して投影されたパターン像に露光される。投影系またはスキャニング露光装置において、マスク（また

は、レチクル）と感光性基板とは、パターン像が投影されながら結像系に対して相対的に移動し、また、これらの種類の露光装置（アライナー）における焦点位置やチルトを検出するのに適切な系に対して相対的に移動する。

【0036】本願発明の露光装置及び露光方法においては、焦点合わせ制御やチルト制御は、感光性基板上の周辺位置におけるショット領域に関して実行される。

【0037】本願発明のスキャニング露光装置及びスキャニング露光方法によって、焦点検出領域を投影光学系の投影視野に設定することなしに、感光性基板の露光領域に関して、高精度に焦点合わせの制御ができ、また、高精度にチルト制御ができる。

【0038】本願発明の焦点合わせ用のセンサ及び焦点検出方法は、焦点深度を改善するために設計された液浸タイプの投影アライナーや液浸タイプのスキャニングアライナーにおいて、液体に浸された感光性基板の表面の焦点合わせまたはチルトにおける誤差を安定して検出できる。本願発明の焦点合わせ用のセンサ及び焦点検出方法は、小さな作動距離の対物レンズ光学系を有する、製造（加工）装置、描画装置、または検査装置に適している。

【0039】本願発明は、マスク（レチクル）のパターン像を結像視野を通して基板（ウェハ）に投影するための結像系（投影レンズ系）と、結像系に対してスキャニング方向にマスク及び基板を移動させるためのスキャニング機構（レチクルステージまたはウェハXYステージ）と、基板及び結像系を互いに対してZ方向に駆動して投影される像の焦点を合わせるZ一駆動系とを有するスキャニング露光装置に適用可能である。本願発明は、また、マスクのパターン像を投影視野を通して基板に投影するための結像系と、投影されるパターン像に関して基板を位置決めするために、X方向及びY方向に移動する移動可能なステージ機構と、基板及び結像系を互いに対してZ方向に駆動して投影される像の焦点を合わせるZ一駆動系とを有する投影アライナー（すなわち、ステッパー）に適用可能である。

【0040】露光装置すなわちアライナーのスキャニング機構または移動可能なステージは、マスクまたは基板を水平方向に維持するための機構とすることができる。あるいは、露光装置すなわちアライナーのスキャニング機構または移動可能なステージは、マスクまたは基板を水平面から、ある一定の角度に維持するための機構としてもよい。例えば、マスクまたは基板を垂直な姿勢で維持しながら、マスクまたは基板を水平または垂直方向に移動させるための垂直（縦置き）ステージ機構としてもよい。この場合、マスクまたは基板が移動する平面は、X方向とY方向に対向している。X方向及びY方向の各々に対して直交しているZ方向も、参照される（例えば、Z方向は、横方向に配置された投影光学系の光軸の方向、または、主光線の方向に一致している）。

【0041】本願発明によれば、アライナーには、第1の検出系と、第2の検出系と、第3の検出系とが設けられている。第1の検出系は、第1の位置に、検出領域を備えている。第1の位置は、結像系の結像視野の外側に設けられ、スキャニング方向（Y方向）において前記結像系の結像視野から間隔をあけて設けられている。第1の検出系は、基板の表面（上面）のZ方向における位置を検出する。第2の検出系は、第2の位置に、検出領域を備えている。第2の位置は、結像系の結像視野の外側に設けられ、スキャニング方向（Y方向）に直交する方向（X）において前記第1の位置から間隔をあけて設けられている。第2の検出系は、基板の表面のZ方向における位置を検出する。第3の検出系は、第3の位置に、検出領域を備えている。第3の位置は、結像系の結像視野の外側に設けられ、スキャニング方向（Y方向）と直交する方向（X方向）において前記結像系の結像視野から間隔をあけて設けられている。第3の位置は、また、スキャニング方向（Y方向）において前記第2の位置からも間隔をあけて設けられている。第3の検出系は、基板の表面のZ方向における位置を検出する。

【0042】本願発明によれば、アライナーには、さらに、第1の検出系によって検出された第1のZ位置と目標Z位置との間のずれを計算し、第1の検出系によって検出される時に、第2の検出系によって検出された第2のZ位置を一時的に記憶するための計算器と；スキャニング機構または移動可能なステージ機構により引き起こされた移動によって、第1の検出系の検出領域に対応する基板上の領域が、結像系の結像視野に位置決めされたとき、計算されたずれと、記憶された第2のZ位置と、第3の検出系によって検出された第3のZ位置とに基づいて、Z一駆動系を制御するためのコントローラとが；設けられている。

【0043】本願発明は、スキャニング露光方法に適用可能である。このスキャニング露光方法においては、投影光学系を通してマスクパターンの一部を感光性基板に投影することによって、また、投影光学系の投影視野に対してマスクと感光性基板とを同時に移動させることによって、マスク（レチクル）のパターンの全てが、感光性基板（ウェハ）に転写される。

【0044】本願発明の方法は、感光性基板の表面高さと実質的に等しい高さで感光性基板を囲むように形成された補助プレート部を有するホルダーに感光性基板を取り付けるためのステップと、感光性基板上の露光領域の焦点誤差を事前に読み取るステップとを備えている。マスクのパターンの一部が前記感光性基板上の領域に投影されるようになっている。ホルダーと感光性基板とをスキャニング移動している間で、露光領域が投影光学系の投影視野に到達する前に、露光領域の焦点誤差が読み取られる。前記本願発明の方法は、さらに、感光性基板上

の露光領域が投影視野に到達したときに、スキャニング移動の方向（Y方向）に対して直交する方向（X方向）において投影光学系の投影視野から離れて配置された露光位置焦点検出系によって、感光性基板または補助プレート部の一部の表面の焦点誤差を検出するステップと、感光性基板上の露光領域の焦点誤差が、投影光学系の投影視野において補正されるように、検出された焦点誤差に基づいて、投影光学系と感光性基板との間の距離を調節するステップとを備えている。

【0045】製造（加工）装置、結像装置、及び検査装置用に適した焦点検出センサまたは焦点検出方法が、上述した露光装置（アライナー）または露光方法のための使用される投影光学系の代わりに、製造、描画、結像、または検査のための対物レンズ光学系を使用することによって、同様に達成される。

【0046】

【発明の実施の形態】図1は、本願発明の第1の実施例における投影露光装置の全体構造を示している。第1の実施例の投影露光装置は、レンズ・スキャンタイプの投影アライナーである。その投影アライナーにおいては、レチクル上の回路パターンが、縮小投影レンズ系を通して、半導体ウェハに投影される。前記縮小投影レンズ系は、物体側でテレセントリック系に形成された円形の像視野と、像側でテレセントリック系に形成された円形の像視野とを有している。一方、レチクルとウェハは、投影レンズ系に対して移動して、スキャン（走査）されるようになっている。

【0047】図1に示された照明系は、193nmの波長を有するパルス光を発するためのArFエキシマーレーザー光源と、前記光源から発するパルス光の断面を所定の形状に形成するためのビームエキスパンダーと、所定の形状に形成された前記パルス光を受けることによって2次光源像（1セットの複数の点光源）を形成するためのフライアイレンズのような光学的インテグレータと、前記2次光源像からの前記パルス光を、一様な照度分布を有するパルス照明光に集光するための集光レンズ系と、スキャニング露光のときのスキャニング方向に対して直交する方向に細長い長方形にパルス照明光を整形するためのレチクルブラインド（照明視野絞り）と、図1に示されたミラー11と集光レンズ系12と協働して、レチクルブラインドの長方形の開口部をレチクルRに結像するためのリレー光学系とを備えている。

【0048】レチクルRは、真空吸引力によって、レチクルステージ14で支持されている。レチクルステージ14は、スキャニング露光の間、大きなストロークで1次元的に、一定速度で移動することができる。レチクルステージ14は、図1で見て横方向に、アライナー本体の柱状構造体13上で案内されて移動し、スキャニング（走査）できるようになっている。レチクルステージ14は、また、図1の平面に対して直交する方向に移動できるように案内される。

【0049】XY平面におけるレチクルステージ14の、座標位置と微妙な回転ずれは、レーザー干渉計システム（IFM）17によって、連続的に測定される。レーザー干渉計システム17は、レチクルステージ14の一部に取り付けられた移動鏡（平面鏡またはコーナー鏡）16にレーザービームを射出する。レーザー干渉計システム17は、移動鏡16によって反射されたレーザービームを受ける（すなわち、受光する）。レチクルステージコントローラー20は、レーザー干渉計システム17によって測定されたXY－座標位置に基づいてレチクルステージ14を駆動する（リニアモーターまたはボイスコイルのような）モーター15を制御する。それによって、レチクルステージ14のスキャニング移動とステッピング移動が制御される。

【0050】レチクルRの回路パターン領域の一部が、集光レンズ系12から発せられた長方形に形成されたパルス光で照らされるとき、その照らされた部分の回路パターンから出る結像光ビームが、1／4（すなわち、4分の1）縮小投影レンズ系PLを通して、ウェハWの上面（すなわち、主要面）に塗布された感光性レジスト層に投影され、そして、結像する。1／4縮小投影レンズ系PLの光軸AXは、円形の像視野の中心点を通って伸長するように、また、照明系10の光軸と集光レンズ系12の光軸とに同軸になるように位置決めされている。

【0051】1／4縮小投影レンズ系PLは、複数のレンズ素子を備えている。レンズ素子は、例えば、193nmの波長を有する紫外線に対して、高い透過率を有する石英や蛍石のような2つの異なった材料から構成されている。蛍石は、正力（positive power）を有するレンズ素子を形成するために、主に使用される。1／4縮小投影レンズ系PLのレンズ素子が固定された鏡筒の空気は、窒素ガスに置き換えられている。これによって、酸素による、193nmの波長を有するパルス照明光の吸収を避けることができる。照明系10の内側から集光レンズ系12にかけての光路に関しても、同様に窒素ガスに置き換えられている。

【0052】ウェハWは、ウェハホルダー（チャック）WHに保持されている。ウェハホルダーWHは、真空吸引によって、ウェハの裏面（後側面）を引き付けている。環状の補助プレート部HRSが、ウェハWの周囲を囲むように、ウェハホルダーWHの周辺部に設けられている。環状の補助プレート部HRSの表面の高さは、ウェハホルダーWHの上面に取り付けられたウェハホルダーWHの上面と実質的に同一平面となっている。下記で詳細に説明するように、ウェハW上の周辺位置にあるショット領域を走査露光するときに、もし、焦点合わせ用のセンサの検出ポイント（すなわち、検出点）が、ウェハWの輪郭エッジの外側に位置決めされているならば、環状の補助プレート部HRSは、代わりの焦点検出面と

して使用される。

【0053】さらに、環状の補助プレート部ＨＲＳは、（Ｓｕｗａに付与された）上記米国特許第４，６５０，９８３に開示されているように、焦点合わせ用のセンサの系オフセットを較正するための平坦な基準プレート（参照プレート）として機能する。言うまでもなく、特別の基準プレートを別に設けて、焦点合わせ用のセンサを較正するようにしてもよい。

【0054】ウェハホルダーＷＨは、ＺＬステージ３０に取り付けられている。ＺＬステージ３０は、１／４縮小投影レンズ系ＰＬの光軸ＡＸに沿ってＺ方向に並進運動できる。また、ＺＬステージ３０は、ＸＹ平面に対してチルト運動している間、光軸ＡＸに対して直交する方向にも移動できる。ＺＬステージ３０は、３つのＺ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃを介して、ＸＹステージ３４に取り付けられている。ＸＹステージ３４は、ベース上で、Ｘ方向及びＹ方向に２次元に移動可能となっている。Ｚ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃの各々は、例えば、ピエゾ伸縮素子、ボイスコイルモーター、または、ＤＣモーターとリフト・カム機構の組み合わせとなっている。

【0055】もし、Ｚ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃ（すなわち、Ｚ－駆動モーター）の各々がＺ方向に同じ量だけ駆動されたならば、ＺＬステージ３０は、ＸＹステージ３４との間が平行に維持されながら、Ｚ方向（すなわち、焦点合わせを行う方向）に並進運動する。もし、Ｚ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃの各々が、Ｚ方向に異なる量だけ駆動されたならば、それによって、ＺＬステージ３０のチルト（傾斜）量とチルト方向が、調節される。

【0056】ＸＹステージ３４の2次元移動は、いくつかの駆動モーター３６によって引き起こされる。駆動モーター３６は、例えば、送りねじを回転させるＤＣモーター（すなわち、直流電動機）や非接触状態で駆動力を生成することができるリニアモーターなどとなっている。駆動モーター３６は、ウェハステージコントローラー３５によって制御されている。ウェハステージコントローラー３５には、移動鏡３１の反射面のＸ方向及びＹ方向における位置の変化を測定できるように、レーザー干渉計（ＩＦＭ）３３からの測定座標位置が供給される。

【0057】例えば、駆動モーター３６としてリニアモーターを使用するＸＹステージ３４の全体構造は、１９８６年9月１８日に公開された特開昭第６１－２０９８３１（立石電気株式会社）に開示されているようなものにすることができる。

【0058】この実施例に関して、１／４縮小投影レンズ系ＰＬのワークディスタンス（作動距離）は、非常に小さくなっており、そのため、斜入射光のタイプの焦点合わせ用のセンサの投影ビームは、像面に最も近い１／４縮小投影レンズ系ＰＬの光学素子の表面とウェハＷの上面との間のスペースを通って、ウェハの表面に導くことができないと考えられる。この実施例においては、そのため、オフアクシスタイプ（１／４縮小投影レンズ系ＰＬの投影視野の外側に焦点検出ポイントを備えている）の3つの焦点検出系ＧＤＬ、ＧＤＣ、及びＧＤＲが、１／４縮小投影レンズ系ＰＬのバレル（鏡筒）の下方端部周辺に配置されている。

【0059】これらの焦点検出系のうち、焦点検出系ＧＤＬとＧＤＲは、スキャニング露光のときのウェハＷのスキャニング移動の方向に対して、投影視野の前側及び後ろ側に位置決めされた焦点検出ポイント（焦点検出点）を備えるように設定されている。ウェハＷの１つのショット領域がスキャンされ露光されたとき、スキャニング移動の方向（プラス方向またはマイナス方向）にしたがって選択された焦点検出系ＧＤＬ及びＧＤＲの一方が作動して、長方形の投影像が、ウェハに露光される前に、ショット領域の表面の高さ位置における変化を先読みされる。

【0060】したがって、焦点検出系ＧＤＬ及びＧＤＲは、例えば、（サカキバラなどに付与された）米国特許第５，４４８，３３２に開示された焦点検出系の先読みセンサと同じように機能する。しかしながら、この実施例においては、米国特許第５，４４８，３３２の焦点調節（あるいはチルト調節）のシーケンスとは異なったシーケンスを使用しており、そのため、特別な焦点検出系が焦点検出系ＧＤＬ及びＧＤＲに加えられている。この構造は、下記により詳細に説明されている。

【0061】図１に示された焦点検出系ＧＤＣは、ウェハＷの表面（すなわち、ＸＹ平面）で見たときに、１／４縮小投影レンズ系ＰＬの投影視野のスキャニング方向に対して直交する非スキャニング方向にオフアクシス方式で配置された検出ポイント（検出点）を備えている。しかしながら、焦点検出系ＧＤＣは、図１で見て、１／４縮小投影レンズ系ＰＬの前側の検出ポイントに加えて、１／４縮小投影レンズ系ＰＬの後ろ側に他の検出ポイントを備えている。

【0062】本願発明にしたがった焦点検出方法は、オフアクシス焦点検出系ＧＤＣと、先読み焦点検出系ＧＤＬ及びＧＤＲの一方とが、互いに協働して作動するようになっているという点に特徴がある。これらの焦点検出系の詳細な説明は、後述する。

【0063】上述した焦点検出系ＧＤＬ、ＧＤＲ、及びＧＤＣの各々によって検出されたウェハ表面の一部の高さ位置に関する情報（例えば、最良の焦点位置からのずれ量を表す誤差信号など）が、自動焦点合わせ（ＡＦ）コントロールユニット３８に入力される。ＡＦコントロールユニット３８は、焦点検出系ＧＤＬ、ＧＤＲ、及びＧＤＣから供給された検出情報に基づいて、Ｚ－アクチュエータとしてのＺ－駆動モーター３２Ａ、３２Ｂ、及

び３２Ｃの各々を駆動する最適な量を決定し、Ｚ－駆動モーター３２Ａ、３２Ｂ、及び３２Ｃを駆動して、投影像が実際に結像するウェハＷの領域に対して、焦点合わせを行うと共に、チルト調節を行う。

【００６４】この制御のために、焦点検出系ＧＤＬ及びＧＤＲの各々は、マルチポイント（多点）焦点合わせ用のセンサとなっている。このセンサは、１／４縮小投影レンズ系ＰＬによって形成されるウェハＷ上の長方形投影領域における複数位置（例えば、少なくとも２つの位置）に検出ポイントを有している。ＡＦコントロールユニット３８は、焦点合わせはもちろん、少なくとも非スキャニング方向（Ｘ方向）においてウェハＷをチルト調節できるようになっている。

【００６５】図１に示されたアライナーは、一定速度でＹ方向にＸＹステージ３４を移動することによって、スキャニング露光を行うように構成されている。スキャニング露光の間の、レチクルＲ及びウェハＷのスキャニング移動とレチクルＲ及びウェハＷのステッピング移動との関係を、図２を参照して説明する。

【００６６】図２を参照すると、前方グループレンズ系ＬＧａと後方グループレンズ系ＬＧｂが、図１に示された１／４縮小投影レンズ系ＰＬを表している。射出瞳Ｅｐが、前方グループレンズ系ＬＧａと後方グループレンズ系ＬＧｂとの間に存在している。回路パターン領域Ｐａは、図２に示されたレチクルＲ上で、遮蔽帯ＳＢによって画定されたフレーム（枠）に形成されている。回路パターン領域Ｐａは、１／４縮小投影レンズ系ＰＬの物体側上に形成される円形の像視野の直径よりも大きい対角線長さを有している。

【００６７】スキャニング方式で、レチクルＲの回路パターン領域Ｐａの像が、ウェハＷ上の対応するショット領域ＳＡａに露光される。このスキャニング方式は、例えば、レチクルＲを一定の速度ＶｒでＹ軸に沿ったマイナス方向に移動する一方、ウェハＷを一定速度ＶｗでＹ軸に沿ったプラス方向に移動することによって行われる。このとき、レチクルＲを照明するためのパルス照明光ＩＡの形状は、図２に示すように、レチクルＲの回路パターン領域ＰａにおいてＸ方向に細長い平行ストリップまたは長方形に設定されている。Ｘ方向において互いに対向している、パルス照明光ＩＡの形状の両端は、遮蔽帯ＳＢに位置決めされている。

【００６８】パルス照明光ＩＡで照射される、レチクルＲの回路パターン領域Ｐａの長方形領域に含まれている部分的パターンは、１／４縮小投影レンズ系ＰＬ（前方グループレンズ系ＬＧａ及び後方グループレンズ系ＬＧｂ）によって、ウェハＷのショット領域ＳＡａでの対応位置に、像ＳＩとして結像する。レチクルＲ上の回路パターン領域ＰａとウェハＷ上のショット領域ＳＡａとの間での相対的なスキャニングが完了したとき、例えば、ウェハＷは、Ｙ方向に一定の距離だけ１ステップ移動する。それによって、スキャニングの開始位置は、ショット領域ＳＡａに隣接するショット領域ＳＡｂに対して設定される。このステッピング動作の間、パルス照明光ＩＡによる照明は、停止している。

【００６９】次に、スキャニング方式で、レチクルＲの回路パターン領域Ｐａの回路パターン像を、ウェハＷ上のショット領域ＳＡｂに露光するために、レチクルＲは、パルス照明光ＩＡに対してＹ軸のプラス方向に一定速度Ｖｒで移動する。そして、ウェハＷは、同時に、投影された像ＳＩに対してＹ軸のマイナス方向に一定速度Ｖｗで移動する。速度比Ｖｗ／Ｖｒは、１／４縮小投影レンズ系ＰＬの縮小比１／４に設定されている。上記スケジュールにしたがって、レチクルＲの回路パターン領域Ｐａの像が、ウェハＷ上の複数のショット領域に露光される。

【００７０】図１及び図２に示された投影アライナーは、次のような方法で、ステップアンドリピート方式のアライナーとして使用できる。すなわち、もし、レチクルＲ上の回路パターン領域Ｐａの対角線長さが、１／４縮小投影レンズ系ＰＬの回路像視野の直径よりも小さいならば、照明系１０におけるレチクルブラインドの開口部の形状およびサイズが変化し、それによって、パルス照明光ＩＡの形状が回路パターン領域Ｐａに一致するようになっている。そのような場合、レチクルステージ１４とＸＹステージ３４とは、ウェハＷ上のショット領域の各々を露光する間、相対的に静止した状態に維持される。

【００７１】しかしながら、もし、ウェハＷが露光の間にわずかに移動するならば、ウェハＷのわずかな移動は、レーザー干渉計システム３３によって測定することができる。また、レチクルステージ１４を制御下でわずかに移動して、その結果、レチクルＲ側で追従補正することにより、１／４縮小投影レンズ系ＰＬに対するウェハＷの位置の対応する小さな誤差を打ち消すことができる。例えば、そのような追従補正のためのシステムは、特開平６－２０４１１５号と特開平７－２２０９９８号に開示されている。これらの公開公報に開示された技術は、必要に応じて使用することができる。

【００７２】もし、レチクルブラインドの開口部の形状やサイズが変化するならば、ズームレンズ系を設けることにより、光源からレチクルブラインドに到達するパルス照明光ＩＡを、開口部の形状やサイズの変化に応じて、調節された開口部に整合する範囲内に集めることができる。

【００７３】図２に明瞭に示されているように、投影された像ＳＩの領域は、Ｘ方向に細長いストリップ形状または長方形形状に設定されることから、スキャニング露光の間のチルト調節は、Ｙ軸を中心として回転する方向、すなわち、この実施例におけるスキャニング露光方向に対するローリング方向に沿ってのみ行うことができ

る。言うまでもなく、もし、投影された像ＳＩ領域の、スキャニング方向における幅が、スキャニング方向に対してウェハ表面の平面度の影響を考慮する必要がある程度に大きいならば、スキャニング露光の間に、ピッチング方向におけるチルト調節が行われる。この作動は、本願発明の他の実施例に関してより詳細に説明する。

【００７４】図1に示された焦点検出系ＧＤＬ、ＧＤＲ、及びＧＤＣは、例えば、図3に図示されたように配置されている。図3は、１／４縮小投影レンズ系ＰＬの像側で円形の像視野ＣＰが形成される平面上での焦点検出系の検出ポイントの配置を示している斜視図である。図3は、焦点検出系ＧＤＬ及びＧＤＣの配置のみ示している。焦点検出系ＧＤＲは省略されている。というのは、焦点検出系ＧＤＲは、焦点検出系ＧＤＬと同じ構造だからである。

【００７５】図3を参照すると、焦点検出系ＧＤＣは、２つの検出器ＧＤＣ１及びＧＤＣ２を備えている。検出器ＧＤＣ１及びＧＤＣ２は、検出ポイント（検出領域）ＦＣ１及びＦＣ２が、ストリップ状で長方形の投影された像ＳＩの軸線から伸長する延長線ＬＬｃ上に位置決めされるように設定されている。ストリップ状で長方形の投影された像ＳＩは、１／４縮小投影レンズ系ＰＬの円形の像視野ＣＰで、直径方向（Ｘ方向）に伸長している。これらの検出器ＧＤＣ１及びＧＤＣ２は、ウェハＷ（または、補助プレート部ＨＲＳ）の上面の高さ位置や最良の焦点平面位置に対するＺ方向の位置誤差量を検出する。

【００７６】一方、焦点検出系ＧＤＬは、本実施例において、5つの検出器ＧＤＡ１、ＧＤＡ２、ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３を備えている。検出器ＧＤＡ１、ＧＤＡ２、ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３は、それぞれ、検出ポイント（検出領域）ＦＡ１、ＦＡ２、ＦＢ１、ＦＢ２、及びＦＢ３を備えている。検出ポイントＦＡ１、ＦＡ２、ＦＢ１、ＦＢ２、及びＦＢ３は、延長線ＬＬｃに平行な直線ＬＬａに位置決めされている。これらの5つの検出器ＧＤＡ１、ＧＤＡ２、ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３の各々は、独立して、ウェハＷ（または、補助プレート部ＨＲＳ）の上面におけるポイントの高さ位置や最良の焦点平面位置に対するＺ方向の位置誤差量を検出する。

【００７７】延長線ＬＬｃや直線ＬＬａは、スキャニング方向（Ｙ方向）に互いに一定距離をおいて設定されている。また、検出器ＧＤＡ１の検出ポイントＦＡ１と、検出器ＧＤＣ１の検出ポイントＦＣ１とは、Ｘ方向において、実質的に同じ座標位置に設定されている。一方、検出器ＧＤＡ２の検出ポイントＦＡ２と、検出器ＧＤＣ２の検出ポイントＦＣ２とは、Ｘ方向において、実質的に同じ座標位置に設定されている。

【００７８】3つの検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３の検出ポイントＦＢ１、ＦＢ２、及びＦＢ３は、ストリップ状のまたは長方形の投影された像ＳＩの領域をＸ方向において覆うように配置されている。すなわち、検出ポイントＦＢ２は、投影された像ＳＩの領域のＸ方向における中心（光軸ＡＸが通るポイント）に対応するＸ座標位置に配置されている。一方、検出ポイントＦＢ１及びＦＢ３は、投影された像ＳＩのＸ方向における両端付近の位置に対応するＸ座標位置に配置されている。そのため、3つの検出ポイントＦＢ１、ＦＢ２、及びＦＢ３を使用して、投影された像ＳＩ領域に対応するウェハＷの表面部での焦点誤差を先読みできるようになっている。

【００７９】図3に図示されていない焦点検出系ＧＤＲにも、3つの先読み検出器ＧＤＥ１、ＧＤＥ２、及びＧＤＥ３と他の２つの検出器ＧＤＤ１及びＧＤＤ２とを備えている。検出器ＧＤＤ１及びＧＤＤ２は、先読み検出器ＧＤＥ１、ＧＤＥ２、及びＧＤＥ３のＸ方向の両側に配置されている。説明を簡単にするために、この実施例においては、１２個の検出器ＧＤＡ１、ＧＤＡ２；ＧＤＢ１、ＧＤＢ２、ＤＢ３；ＧＤＣ１、ＧＤＣ２；ＧＤＤ１、ＧＤＤ２；ＧＤＥ１、ＧＤＥ２、ＧＤＥ３によって複数の最良の焦点位置として認められる複数の平面は、１つのＸＹ平面に調節されるものと仮定する。すなわち、システム上のオフセットが１２個の検出器の間にはない。また、検出された焦点誤差がゼロになる位置として、１２個の検出ポイントＦＡ１、ＦＡ２；ＦＢ１、ＦＢ２、ＦＢ３；ＦＣ１、ＦＣ２；ＦＤ１、ＦＤ２；ＦＥ１、ＦＥ２、ＦＥ３で検出されたウェハＷの表面高さ位置は、互いに対してほぼ接近しているものと仮定する。

【００８０】１／４縮小投影レンズ系ＰＬの端が液体に浸されていないならば、上述した１２個の焦点検出器として、光学センサ、空気マイクロメータタイプのセンサ、静電容量タイプのギャップ（間隙）センサなどを使用できる。しかしながら、もし、液浸式の投影系が形成されているならば、もちろん、空気マイクロメータタイプのセンサを使用することはできない。

【００８１】図4は、図1及び図3に示された焦点検出系ＧＤＬ、ＧＤＲ、及びＧＤＣからの検出信号（誤差信号）を処理するためのＡＦコントロールユニット３８の一例のブロック線図である。図4に示されているように、先読み焦点検出系ＧＤＬの５つの検出器ＧＤＡ１、ＧＤＡ２、ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３からの検出信号のグループと、焦点検出系ＧＤＲの５つの検出器ＧＤＤ１、ＧＤＤ２、ＧＤＥ１、ＧＤＥ２、及びＧＤＥ３からの検出信号のグループのうちの一方のグループが、切換え回路５０によって選択されて、その後の処理回路に供給される。

【００８２】切換え回路５０は、位置監視回路（位置モニター回路）５２から供給される（方向の区別の結果を表す）切換え信号ＳＳ１に応答して、焦点検出系ＧＤＬ及びＧＤＲのうちの一方からの信号を選択する。位置監

視回路５２は、ウェハステージコントローラー３５からのステージ制御情報に基づいて、ウェハステージ３４のスキャニング移動方向の一方の移動方向を他方の移動方向から区別する。また、位置監視回路５２は、先読み位置から露光位置まで、ウェハWの移動した位置の変化を監視している。図4に示された状態においては、切換え回路５０は、焦点検出系ＧＤＬからの５つの検出信号を選択している。

【００８３】露光領域（投影された像ＳＩ）に関する先読み検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ3からの検出信号は、焦点誤差量とチルト誤差量とを計算するための第１の計算器５４に供給される。第１の計算器５４は、第２の計算及び記憶回路５６に、３つの検出ポイントＦＢ１、ＦＢ２、及びＦＢ３で事前に読取られたウェハWの表面領域の焦点誤差量ΔＺｆとチルト誤差量ΔＴｘ（Y軸を中心とした微妙な傾き）に関する誤差データＤＴ１、ＤＴ２とを供給する。

【００８４】一方、検出器ＧＤＡ１及びＧＤＡ２は、第２の計算及び記憶回路５６に、情報ＺＡ１と情報ＺＡ２とを供給する。情報ＺＡ１は、検出ポイントＦＡ１における表面の高さ位置（すなわち、焦点ずれ）を表している。情報ＺＡ２は、検出ポイントＦＡ２における表面の高さ位置（すなわち、焦点ずれ）を表している。情報ＺＡ１及び情報ＺＡの検出は、３つの検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３によるウェハ表面の検出と同時に行われている。

【００８５】誤差データＤＴ１及びＤＴ２と、情報ＺＡ１及びＺＡ２と、検出器の間の相対位置関係とに基づいて、第２の計算及び記憶回路５６は、Y方向（スキャニング方向）に関して投影露光位置に設定された検出器ＧＤＣ１及びＧＤＣ２の検出ポイントＦＣ１及びＦＣ２で検出されるべきウェハWの高さ位置の目標値ΔＺ１及びΔＺ２を計算する。第２の計算及び記憶回路５６は、一時的に、計算された目標値ΔＺ１及びΔＺ２を記憶する。

【００８６】目標値ΔＺ１及びΔＺ２の意味は、次の通りである。すなわち、先読み検出ポイントＦＡ１及びＦＡ２で事前に読み取られたウェハW（または、環状の補助プレート部ＨＲＳ）の表面部が、対応する露光位置での検出ポイントＦＣ１及びＦＣ２に到達するときに、検出器ＧＤＣ１及びＧＤＣ２によって検出された情報ＺＣ１と情報ＺＣ２が、目標値ΔＺ１及びΔＺ２にそれぞれ等しいならば、先読みによって決定される焦点誤差量ΔＺｆとチルト誤差量ΔＴｘは、露光位置でゼロになる。

【００８７】さらに、先読みされたウェハ上のY方向に関する領域が、投影像ＳＩが露光される露光位置に到達する直前に、第２の計算及び記憶回路５６は、記憶された目標値ΔＺ１及びΔＺ２を第３の計算及び駆動回路５８に出力する。

【００８８】したがって、位置監視回路５２から出力された信号ＳＳ２に同期して、第２の計算及び記憶回路５６は、一時的に記憶された目標値ΔＺ１及びΔＺ２を表す信号を第３の計算及び駆動回路５８に出力する。目標値ΔＺ１及びΔＺ２を表す前記信号は、Y方向における直線ＬＬａと延長線ＬＬｃとの間の距離と、ウェハWの移動速度と、によって決定される時間だけ遅延させられた後に、第３の計算及び駆動回路５８に出力される。

【００８９】スキャニング方向における、投影像ＳＩの幅に対応する距離だけ、ウェハWが移動してスキャンされる毎に、信号ＳＳ２が出力されるならば、図3に示された、直線ＬＬａと延長線ＬＬｃとの間のY方向における距離（例えば、約４０ｍｍ）を、投影像ＳＩの幅（約８ｍｍ）で除算することによって得られた数に対応する一定の数の組（例えば、５組）の目標値ΔＺ１及びΔＺ２が、第２の計算及び記憶回路５６に記憶される。したがって、第２の計算及び記憶回路５６は、先入れ先出し（ＦＩＦＯ）方法で目標値ΔＺ１及びΔＺ２を記憶するメモリとして機能する。

【００９０】第3の計算及び駆動回路５８は、位置監視回路５２からの信号ＳＳ３に応答して、検出器ＧＤＣ１及びＧＤＣ２によって検出されたウェハW（または、環状の補助プレート部ＨＲＳ）の表面の高さ位置に関する検出情報ＺＣ１及びＺＣ２を読み取る。その直後に、先読み位置で検出されたウェハW上の領域が、露光位置（投影された像ＳＩの位置）に到達する。

【００９１】同時に、第3の計算及び駆動回路５８は、第２の計算及び記憶回路５６から出力された（露光位置に対応する）目標値ΔＺ１及びΔＺ２のデータを読み取る。そして、第3の計算及び駆動回路５８は、検出情報ＺＣ１及びＺＣ２と目標値ΔＺ１及びΔＺ２とに基づいて、図1に示されたＺ－駆動モーター３２Ａ、３２Ｂ、及び３２Ｃに対応する駆動量（位置調節の量や速度調節の量）を、計算によって決定する。次いで、第3の計算及び駆動回路５８は、その決定された駆動量のデータをＺ－駆動モーター３２Ａ、３２Ｂ、及び３２Ｃに出力する。

【００９２】図4のほとんどの構成要素は、図4の観点から当業者によって書くことができる適切なプログラムを実行するプログラムされたマイクロコントローラーやマイクロプロセッサで具体化される。

【００９３】図5は、図1に示されたようなウェハホルダーの周辺部に形成された環状の補助プレート部ＨＲＳの機能を説明する平面図である。この実施例において、焦点検出系の全ての検出ポイントは、上述したような１／４縮小投影レンズ系ＰＬの投影視野ＣＰの外側に位置決めされていることから、ウェハW上の複数のショット領域ＳＡｎのうち該ウェハWの周辺部に配置されたいくつかのショット領域をスキャニング露光するときに、いくつかの焦点検出ポイントが、ウェハWの周辺の外側に置かれる可能性がある。

【0094】例えば、図5に示されているように、プリアライメントされた（事前にアライメントされた）切欠きＮＴを使用してウェハホルダーWH上に位置決めされたウェハWの周辺のショット領域ＳＡ１が、走査露光されるとき、先読み焦点検出系ＧＤＬ（またはＧＤＲ）の、端にある焦点検出ポイントＦＡ１（またはＦＤ１）と、露光位置の焦点検出系ＧＤＣの検出ポイントＦＣ１とは、ウェハWの外側に置かれる。この場合、焦点合わせ及びチルト調節を行うことは、通常は困難である。

【0095】環状の補助プレート部ＨＲＳの主な機能は、そのような場合に、通常の焦点合わせとチルト運動を可能にすることである。図5に示されているように、ウェハWの外側に置かれた検出ポイントＦＡ１（またはＦＤ１）と検出ポイントＦＣ１は、環状の補助プレート部ＨＲＳの表面に位置決めされるように設定されている。したがって、環状の補助プレート部ＨＲＳの表面の高さは、ウェハWの表面の高さに実質的に等しいことが望ましい。

【0096】より具体的に説明すると、ウェハWの表面と環状の補助プレート部ＨＲＳの表面とは、検出ポイントＦＡ１（ＦＡ２）、ＦＣ１（ＦＣ２）、及びＦＤ１（ＦＤ２）に対応する検出範囲内で、互いに対し同一平面上にある。その検出範囲において、検出ポイントに対応する焦点検出器の所望の線形性が、確保されている。さらに、環状の補助プレート部ＨＲＳの表面がウェハWの表面の代わりとして使用されていることから、その補助プレート部ＨＲＳの反射率は、標準の（シリコン）ウェハの反射率と同じ程度かあるいは同じ値となっている。例えば、環状の補助プレート部ＨＲＳとしては、鏡面仕上げされた表面が好ましい。

【0097】（ウェハホルダーWH上の）ウェハWが、図5に示された矢印の方向に移動してスキャンされたならば、焦点検出系ＧＤＬの検出ポイントＦＡ１、ＦＡ２；ＦＢ１、ＦＢ２、ＦＢ3は、ショット領域ＳＡ1に関する先読みセンサとして選択される。この場合、投影像ＳＩのY方向におけるに中心に対応する延長線ＬＬｃと、焦点検出系ＧＤＬの検出ポイントが配置される直線ＬＬａとの間の距離を、ＤＬａとし、また、延長線ＬＬｃと、他方の焦点検出系ＧＤＲの検出ポイントが配置される直線ＬＬｂとの間の距離を、ＤＬｂとすれば、この実施例においては、ＤＬａとＤＬｂは、ＤＬａがＤＬｂにほぼ等しくなるように設定される。スキャニング露光のときのウェハWの速度Ｖwから、ウェハW上の焦点先読み位置が露光位置に到達するのにかかる遅延時間Δｔは、Δｔ＝ＤＬａ／Ｖｗ（秒）となっている。したがって、図4に示された第2の計算及び記憶回路５６において、目標値ΔＺ１及びΔＺ２を一時的に記憶するための時間は、タイムラグ（時間遅れ）Δｔと実質的に等しくなっている。

【0098】しかしながら、距離ＤＬａと距離ＤＬｂは、アライナーの構造に関係する制約に応じて、ＤＬａがＤＬｂに等しくならないように選択するようにしてもよい。言うまでもなく、そのような場合において、目標値ΔＺ１及びΔＺ２の供給の遅延時間は、先読み焦点検出系ＧＤＬの使用と先読み焦点検出系ＧＤＲの使用とに関して、異なる長さに設定されている。

【0099】上述したように構成された第１の実施例の焦点合わせとチルト運動の作用を、図６Ａないし図６Ｄを参照して説明する。図６Ａは、図5に示されたようなウェハWの周辺ショット領域ＳＡ１をスキャニング露光している間のある瞬間に先読み焦点検出系ＧＤＬによって検出された環状の補助プレート部ＨＲＳの上側表面の状態及びウェハWの上側表面の状態を図式的に示している。

【0100】図６Ａないし図６Ｄにおいて、水平ラインＢＦＰは、１／４縮小投影レンズ系ＰＬの最適な焦点面を示している。ショット領域ＳＡ１において検出ポイントＦＢ１でウェハ表面のZ方向における位置を検出する検出器ＧＤＢ１は、平面ＢＦＰに対するウェハ表面のZ位置誤差量（焦点はずれの量、すなわちデフォーカス量）としてΔＺＢ１を表す検出信号を出力する。同様に、検出ポイントＦＢ２及びＦＢ３でウェハ表面のZ方向における位置の誤差を検出する検出器ＧＤＢ２及びＧＤＢ３は、誤差ΔＺＢ２及びΔＺＢ３を表す検出信号を出力する。ウェハ表面が最適な焦点面ＢＦＰよりも下にあるならば、これらＺ位置誤差の各々は、負の値を有している。また、ウェハ表面が最適な焦点面ＢＦＰよりも上にあるならば、Ｚ位置誤差の各々は、正の値を有している。

【0101】これらの誤差ΔＺＢ１、ΔＺＢ２、及びΔＺＢ３の値は、図4に示された第１の計算及び記憶回路５４に入力される。第１の計算及び記憶回路５４は、これらの誤差値に基づいて最小２乗法などにより、ショット領域ＳＡ１における先読みされた部分全体の、図６Ｂに示された近似面ＡＰＰ（実際は、近似直線）を表す数式のパラメータを決定する。それによって決定されたパラメータは、図６Ｂに示されたように、近似面ＡＰＰの焦点誤差量ΔＺｆとチルト誤差量ΔＴｘである。このようにして計算された焦点誤差量ΔＺｆとチルト誤差量ΔＴｘの値は、データＤＴ１及びデータＤＴ２として、第２の計算及び記憶回路５６に出力される。この実施例において、焦点誤差量ΔＺｆは、ショット領域ＳＡ１のX方向における（検出ポイントＦＢ２に対応する）中央ポイントでの実質的な誤差として計算される。

【0102】検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３が、上述したようにＺ位置誤差を検出したとき、検出器ＧＤＡ１及びＧＤＡ２は、検出ポイントＦＡ１及びＦＡ２での最適な焦点面に対する、ウェハ表面または環状の補助プレート部ＨＲＳの表面のＺ位置誤差ΔＺＡ１及びΔＺＡ２を同時に検出する。これらの誤差ΔＺＡ１及び

ΔＺＡ２は、第２の計算及び記憶回路５６に一時的に記憶される。

【０１０３】この検出及び記憶の直後、図６Ｂに示されたような近似面ＡＰＰが、図６Ｃに示されたような最適な焦点面ＢＦＰに一致するように補正されるとすると、すなわち、ウェハホルダーＷＨが、焦点誤差量ΔＺｆ＝０となるように、また、チルト誤差量ΔＴｘ＝０となるように、Ｚ方向及びチルト運動方向に調節されるとすると、第２の計算及び記憶回路５６は、データＤＴ１及びＤＴ２（誤差量ΔＺｆ及びΔＴｘ）と、検出ポイントＦＡ１及びＦＡ２で実際に測定されたＺ位置誤差ΔＺＡ１、ΔＺＡ２と、ショット領域の中央ポイントと検出ポイントＦＡ１及びＦＡ２の各々との間のX方向における距離ＤＳとに基づいて、検出ポイントＦＡ１で検出されるべきＺ位置目標値ΔＺ１と、検出ポイントＦＡ２で検出されるべきＺ位置目標値ΔＺ２とを計算する。ウェハW上の先読みされた領域が、投影像ＳＩ（露光位置）の領域に到達するまで、計算されたＺ位置目標値ΔＺ１及びΔＺ２は、一時的に第２の計算及び記憶回路５６に記憶される。

【０１０４】ウェハW上の先読みされた領域が露光位置に到達したとき、図4に示された第3の計算及び駆動回路５８が、検出ポイントＦＣ１及びＦＣ２でのZ位置誤差を検出するために、検出器ＧＤＣ１及びＧＤＣ２からの検出信号を読み取る。例えば、ウェハW上の先読みされた領域が、露光位置に到達する直前に図６Ｄに示されたような状態にあるならば、検出器ＧＤＣ１は、検出ポイントＦＣ１でのＺ位置誤差を表す検出信号ＺＣ１を出力する。一方、検出器ＧＤＣ２は、検出ポイントＦＣ２でのＺ位置誤差を表す検出信号ＺＣ２を出力する。

【０１０５】次いで、第3の計算及び駆動回路５８は、検出器ＧＤＣ１及びＧＤＣ２から供給される検出信号ＺＣ１及びＺＣ２の値が、それぞれ、遅延して第２の計算及び記憶回路５６から供給されるＺ位置目標値ΔＺ１及びΔＺ２に等しくなるように、ウェハホルダーＷＨをＺ方向においてチルト及び／または並進運動させるために必要な、3つのＺ－アクチュエータ３２Ａ、３２Ｂ、及び３２C用の駆動量を計算する。第3の計算及び駆動回路５８は、前記計算された駆動量に対応する信号を、Ｚ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃに供給する。

【０１０６】ウェハWの上面のショット領域ＳＡ１は、それによって、露光位置で、最適な焦点面ＢＦＰに一致するように正確に調節される。その結果、最適の結像状態に維持されるべきレチクルRのパターンの投影像ＳＩが、ショット領域のスキャニングモードで露光される。

【０１０７】第1の実施例におけるこの作動の間に、先読み焦点検出系ＧＤＬにおける各検出器と、露光位置焦点検出系ＧＤＣにおける各検出器とは、ウェハWの表面または環状の補助プレート部ＨＲＳの表面が、最適な焦点面ＢＦＰに一致したとき、焦点誤差がないということを示す検出信号出力するように設定（較正）される。しかしながら、検出器をそのような状態に厳密に設定することは困難である。特に、先読み焦点検出系ＧＤＬ（ＧＤＲ）における検出器ＧＤＡ１及びＧＤＡ２（ＧＤＤ１及びＧＤＤ２）と、露光位置焦点検出器ＧＤＣ１及びＧＤＣ２との間の検出オフセットが、露光のためにウェハWに形成されたパターン像に一様に焦点はずれをおこさせる。

【０１０８】そのため、検出器ＧＤＣ１がゼロの焦点誤差を検出するＺ方向における高さ位置と、検出器ＧＤＡ１（ＧＤＤ１）がゼロの焦点誤差を検出するＺ方向における高さ位置との間のオフセット値を、ウェハホルダーＷＨに設けられた反射ガラスプレート（すなわち、基準プレート）のきわめて平坦度の高い表面上でこれらの検出器により、焦点検出を同時に行うことによって、測定し記憶するようにしてもよい。この表面は、構造ＨＲＳまたは構造ＨＲＳとは別体の他の構造とすることができる。その結果、Ｚ－アクチュエータ３２Ａ、３２Ｂ、及び３２Ｃが、露光位置焦点検出器ＧＤＣ１及びＧＤＣ２によって検出されたＺ位置誤差に基づいて駆動されるとき、記憶されたオフセット値により補正を行うことができる。

【０１０９】本願発明の第２の実施例に係わる焦点及びチルトセンサの構造を、次に、図7及び図8を参照して説明する。第２の実施例に関しては、１／４縮小投影レンズ系ＰＬの円形の視野に含まれる投影像ＳＩが、Ｙ方向（スキャニング方向）において比較的に大きな最大幅を備えており、それによって、ウェハWの表面のY方向へのチルトの影響、すなわち、ピッチング（縦揺れ）の影響を考慮に入れるべき必要があるという状況が想定されている。

【０１１０】露光位置焦点検出器ＧＤＣ１（図示せず）が設けられており、図7に示されているように、露光位置焦点検出器ＧＤＣ１は、２つの検出ポイントＦＣ１ａ及びＦＣ１ｂを備えている。検出ポイントＦＣ１ａ及びＦＣ１ｂは、投影像ＳＩより上でY方向において延長線ＬＬｃを中心として対称に配置されている。そして、もう一つの露光位置焦点検出器ＧＤＣ２（図示せず）が、設けられている。露光位置焦点検出器ＧＤＣ２は、２つの検出ポイントＦＣ２ａ及びＦＣ２ｂを備えている。検出ポイントＦＣ２ａ及びＦＣ２ｂは、投影像ＳＩより下でY方向において延長線ＬＬｃを中心として対称に配置されている。さらに、先読み焦点検出器ＧＤＡ１と先読み焦点検出器ＧＤＡ２（図示せず）とが設けられている。先読み焦点検出器ＧＤＡ１は、２つの検出ポイントＦＡ１ａ及びＦＡ１ｂを備えている。検出ポイントＦＡ１ａ及びＦＡ１ｂは、Y方向において直線ＬＬａを中心として対称に配置されている。先読み焦点検出器ＧＤＡ２は、２つの検出ポイントＦＡ２ａ及びＦＡ２ｂを備え

ている。検出ポイントＦＡ２ａ及びＦＡ２ｂは、Ｙ方向において直線ＬＬａを中心として対称に配置されている。同様に、先読み焦点検出器ＧＤＤ１（図示せず）と先読み焦点検出器ＧＤＤ２（図示せず）とが設けられている。先読み焦点検出器ＧＤＤ１は、２つの検出ポイントＦＤ１ａ及びＦＤ１ｂを備えている。検出ポイントＦＤ１ａ及びＦＤ１ｂは、Ｙ方向において直線ＬＬｂを中心として対称に配置されている。先読み焦点検出器ＧＤＤ２は、２つの検出ポイントＦＤ２ａ及びＦＤ２ｂを備えている。検出ポイントＦＤ２ａ及びＦＤ２ｂは、Ｙ方向において直線ＬＬｂを中心として対称に配置されている。

【０１１１】先読み焦点検出器ＧＤＢｎ（ｎ＝１，２，３）（図示せず）と、先読み焦点検出器ＧＤＥｎ（ｎ＝１，２，３）（図示せず）とが、また、設けられている。先読み焦点検出器ＧＤＢｎは、複数対の検出ポイントＦＢ１ａ、ＦＢ１ｂ；ＦＢ２ａ、ＦＢ２ｂ；ＦＢ３ａ、ＦＢ３ｂを備えている。先読み焦点検出器ＧＤＥｎは、複数対の検出ポイントＦＥ１ａ、ＦＥ１ｂ；ＦＥ２ａ、ＦＥ２ｂ；ＦＥ３ａ、ＦＥ３ｂを備えている。各対の検出ポイントは、Ｙ方向において互いから離れて一定の間隔をあけて設けられている。

【０１１２】図７に示された焦点検出系は、上述した第１の実施例と同様な方法で、オフアクシス検出器ＧＤＣ１及びＧＤＣ２の検出ポイントにおいて、先読みされた各ショット領域の表面形状（すなわち、誤差量ΔＺｆとΔＴｘ）を補正するために必要な調節量（すなわち、目標値ΔＺ１及びΔＺ２）を再生する。それによって、露光領域の、Ｚ方向における焦点調節とＸ方向（ローリング方向、すなわち横揺れ方向）におけるチルト調節とが可能となっている。

【０１１３】この実施例において、先読み焦点検出系ＧＤＬ（ＧＤＲ）と露光位置焦点検出系ＧＤＣとは、Ｙ方向において一定距離だけ間隔をあけて設けられた複数対の検出ポイント（ＦＡｎａとＦＡｎｂ；ＦＢｎａとＦＢｎｂ；ＦＣｎａとＦＣｎｂ；ＦＤｎａとＦＤｎｂ；ＦＥｎａとＦＥｎｂ）を備えていることから、ピッチング方向における先読みされたショット領域のチルト誤差量ΔＴｙは、Ｙ方向において複数対を形成する検出ポイント（．．．ｎａ、．．．ｎｂ）でのＺ位置誤差の間の差分から検出でき、また、チルト誤差量ΔＴｙを含むショット領域の表面形状を補正するのに必要な調節量（すなわち、目標値ΔＺＡ１、ΔＺＡ２）は、オフアクシス検出器ＧＤＣ１及びＧＤＣ２の検出ポイント（ＦＣｎａ及びＦＣｎｂ）で再生できる。

【０１１４】図３に示された検出ポイントＦＢ１、ＦＢ２、及びＦＢ３で焦点位置を検出するための検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３は、１／４縮小投影レンズ系ＰＬの下方部に固定することによって、互いに独立した系として配置されている。しかしながら、少なくともこれら３つの検出器ＧＤＢ１、ＧＤＢ２、及びＧＤＢ３は、共通の対物レンズ系を通して、検出ポイントＦＢ１、ＦＢ２、及びＦＢ３で焦点位置を検出するように構成することができる。図５に示された検出ポイントＦＢ１、ＦＢ２、及びＦＢ３で焦点位置を検出するための３つの検出器ＧＤＥ１、ＧＤＥ２、及びＧＤＥ３のグループに関しても同じことが言える。

【０１１５】さらに、図７に示された６つの検出ポイントＦＢｎａ及びＦＢｎｂ（ｎ＝１，２，３）で焦点位置を検出する６つの検出器のグループに関して、または、６つの検出ポイントＦＥｎａ及びＦＥｎｂ（ｎ＝１，２，３）で焦点位置を検出する６つの検出器の他のグループに関して、同じ目的のために共通の対物レンズ系を使用してもよい。そのために、複数の検出ポイントで焦点位置を検出する検出器用の共通の対物レンズ系を使用する構成を、図８を参照して簡単に説明する。

【０１１６】図８は、図７でＹ方向で見た、投影レンズと検出器との間の位置的な関係の略側面図である。検出器は、図７に示された、６つの検出ポイントＦＢｎａ及びＦＢｎｂ（ｎ＝１，２，３）と、４つの検出ポイントＦＡ１ａ、ＦＡ１ｂ、ＦＡ２ａ及びＦＡ２ｂとに対応している。したがって、図８におけるウェハＷのスキャニング方向は、当該図８の平面に対して直交する方向である。図７のいちばん左の位置でＸ方向において一列に配置された５つの検出ポイントＦＡ１ａ、ＦＢｎａ（ｎ＝１，２，３）、及びＦＡ２ａが、図８に代表して示されている。もう１つの列の検出ポイントＦＡ１ｂ、ＦＢｎｂ（ｎ＝１，２，３）、及びＦＡ２ｂは、（図８の紙面に対して直交する方向において）５つの検出ポイントＦＡ１ａ、ＦＢｎａ（ｎ＝１，２，３）、及びＦＡ２ａに隣接している。この実施例において、これら１０個の検出ポイントでの焦点位置が、対物レンズ系によって検出される。

【０１１７】図８に示されているように、光源（例えば、発光ダイオード、レーザーダイオード、ハロゲンランプなど）を含む照明光学系８０Ａからの照明光ＩＬＦが、マルチスリットプレート８１Ａに形成された１０個の小スリットの各々を通って発せられる。前記光源は、ウェハＷ上のレジスト層が感光しない波長領域の光りを発することができる。１０個の小スリットは、ウェハＷに設定された１０個の検出ポイントＦＢｎａ、ＦＢｎｂ（ｎ＝１，２，３）、ＦＡ１ａ、ＦＡ１ｂ、ＦＡ２ａ、及びＦＡ２ｂに対応して配置されている。小スリットの透過光は、レンズ系８２Ａと反射鏡８３Ａとを通って、投影系の対物レンズ８４Ａに入射する。そして、所望の角度だけプリズム８５Ａによって偏向させられ、各検出ポイントにスリット像が形成される。

【０１１８】照明光学系８０Ａ、マルチスリットプレート８１Ａ、レンズ系８２Ａ、反射鏡８３Ａ、対物レンズ８４Ａ、及びプリズム８５Ａは、斜入射光タイプの焦点

検出ユニットの投影系を構成している。図8に示された、マルチスリットプレート８１ＡからウェハWにわたる光路の実線は、小スリットから伝達された光りの主光線を表しており、光路における点線は、検出ポイントＦＢ２ａ（またはＦＢ２ｂ）で結像される小スリット結像光の典型的な結像光線ＳＬｆを表している。

【０１１９】ウェハW上の各検出ポイントで反射された小スリット結像光の反射光は、プリズム８５Ｂ、対物レンズ８４Ｂ、反射鏡８３Ｂ、及びレンズ系８２Ｂを通って、受光スリットプレート８１Ｂで再び結像される。プリズム８５Ｂ、対物レンズ８４Ｂ、反射鏡８３Ｂ、及びレンズ系８２Ｂは、前記投影系に対して概ね対称に配置されている。投影マルチスリットプレート８１Ａに設けられた前記小スリットに対応して配置された１０個の受光用の小スリットが、受光スリットプレート８１Ｂに形成されている。これらの受光用の小スリットを伝達した光りは、受光装置８０Ｂによって受光される。受光装置８０Ｂは、複数の光電検出素子となっている。

【０１２０】受光装置８０Ｂの複数の光電検出素子として、１０個の光電検出素子が、ウェハ上の検出ポイントでの焦点位置を個々に検出できるように、受光スリットプレート８１Ｂの小スリットの位置に対応して設けられている。受光装置８０Ｂ、受光スリットプレート８１Ｂ、レンズ系８２Ｂ、反射鏡８３Ｂ、対物レンズ８４Ｂ、及びプリズム８５Ｂは、斜入射光タイプの焦点検出ユニットの受光系を構成している。図8に示されたウェハWから受光スリットプレート８１Ｂに向かう光路の実線は、ウェハWによって通常的に反射された小スリットの主光線を表している。光路における点線は、検出ポイントＦＢ２ａ（またはＦＢ２ｂ）から受光スリットプレート８１Ｂに向かう典型的な結像光線ＲＳｆを表している。

【０１２１】図8に示された投影系と受光系は、一体的に形成された金属製の部材に取り付けられている。それによって、構成要素の位置は、互いに対して正確に維持されている。金属製の部材は、１／４縮小投影レンズ系ＰＬのレンズバレル（鏡筒）に動かないように固定されている。同じ方法で構成されたもう一つの焦点検出ユニットは、１／４縮小投影レンズ系ＰＬの反対側に配置されており、図7に示された１０個の検出ポイントＦＥｎａ、ＦＥｎｂ（ｎ＝１，２，３）、ＦＤ１ａ、ＦＤ２ａ、ＦＤ１ｂ、及びＦＤ２ｂで、焦点位置を個々に検出できるようになっている。

【０１２２】図7に示された前記一対の検出ポイントＦＣ１ａ及びＦＣ１ｂと、前記一対の検出ポイントＦＣ２ａ及びＦＣ２ｂとに関して、図7のY方向（図8の紙面に対して直交する方向）に配置された投影系と受光系の各々を有する斜入射光タイプの焦点検出ユニットは、１／４縮小投影レンズ系ＰＬのX方向における両側に設けるようにしてもよい。焦点検出ポイントが図5に示されたように配置された場合にも、図８に示された斜入射光タイプの焦点検出ユニットを、同じように適用することができる。

【０１２３】次に、本願発明の自動焦点合わせ／チルトコントロール系が適用されるスキャニングアライナーを、図9を参照して本願発明の第３の実施例にしたがって説明する。この実施例は、大きな基板、例えば、直径３００ｍｍあるいはそれ以上の直径を有する基板用のスキャニングアライナーに適用可能である。前記スキャニングアライナーは、１Ｘ（すなわち１倍の）投影光学系を備えている。前記１Ｘの投影光学系は、第１段目のダイソン（Ｄｙｓｏｎ）タイプの（カダディオプトリック（反射屈折））投影結像系と第２段目のダイソン（Ｄｙｓｏｎ）タイプの投影結像系とのタンデム形の（縦に並んだ）組み合わせで形成されている。第１段目のダイソンタイプ（カダディオプトリック）の投影結像系は、一対のプリズムミラーＰＭ１及びＰＭ２と、レンズ系ＰＬ１と、凹面鏡ＭＲ１とを備えている。第２段目のダイソンタイプの投影結像系は、一対のプリズムミラーＰＭ３及びＰＭ４と、レンズ系ＰＬ２と、凹面鏡ＭＲ２とを備えている。そのようなアライナーは、例えば、（Ｓｗａｎｓｏｎなどに付与された）米国特許第５、２９８、９３９号に開示されている。

【０１２４】図9に示されたアライナーにおいて、オリジナルプレートとして設けられたマスクMと、感光性基板として設けられたプレートＰとは、キャリッジ１００に一体的に支持されている。１Ｘ（単一の倍率）の投影光学系の投影視野に対して図9で見てキャリッジ１００を左または右に移動させ、また、マスクM及びプレートＰをスキャン（走査）するように照明光ＩＬを移動させることによって、マスクMに設けられたパターンは、１Ｘ（単一の倍率）の正立像としてプレートＰに転写される。

【０１２５】このタイプのアライナー用の投影光学系の場合、プリズムミラーＰＭ１の入射面とマスクMの表面との間隔と、プリズムミラーＰＭ４の出射面とプレートＰの上面との間隔を最小限にすることにより、結像性能（種々の収差及び像ディストーション（像歪み））の悪化を減少させることが望ましい。換言すれば、もし、これらの間隔を十分に減少させることができるならば、光軸ＡＸ１及びＡＸ２上に配置されたレンズ系ＰＬ１及びＰＬ２の設計は容易となる。そのため、所望の結像性能を達成するために、プリズムミラーＰＭ１とマスクMとの間の間隔と、プリズムミラーＰＭ４とプレートＰとの間の間隔と、を減少することが必要である。

【０１２６】この状態を考慮して、この投影によって投影されたパターン像の焦点合わせをし、そしてパターン像のチルト調節をするために、第１の実施例（図３）や第２の実施例（図７、図８）のような露光位置オフアクシスタイプの焦点検出系ＧＤＣと先読み焦点検出系ＧＤ

Ｌ及びＧＤＲとが、図9に示すようにプリズムミラーＰＭ４の周囲に設けられており、これによって、プレートＰをＺ方向及びチルト方向にわずかに移動させることにより、プレートＰの表面と最適な焦点面ＢＦＰとをプリズムミラーＰＭ４の真下の露光位置で正確に一致させることができる。

【０１２７】さらに、図9に示されたように、先読み焦点検出系ＧＤＬ’及びＧＤＲ’と、露光位置オフアクシスタイプの焦点検出系ＧＤＣ’とを、マスクＭに面するように、マスクＭ側でプリズムミラーＰＭ１の周囲に配置することができる。これらの焦点検出系によって、プリズムミラーＰＭ１に対する照明光ＩＬで照らされるマスクＭの領域の焦点誤差とチルト誤差とを検出でき、また、これと同時に、Ｚ方向におけるわずかなずれ（像面の焦点ずれ）と、プリズムミラーＰＭ４から所定のワーキングディスタンスだけ離れた箇所に形成される最適な焦点面（すなわち、レチクルＲの共役面）のチルトずれ（像面の傾き）と、を測定することができる。

【０１２８】したがって、図9に示されたアライナーにおいて、マスクＭのパターンが投影光学系によって最適な状態で投影され結像される像面と、プレートＰの表面とが、スキャニング露光の間、高精度に互いに対して一致するように調節することができる。

【０１２９】図9に示されたアライナーは、マスクＭとプレートＰとを垂直方向に立設するように構成することができる。図１０は、スキャニングアライナーの典型的な構造の斜視図である。このスキャニングアライナーは、垂直方向に設けられた、すなわち縦置きのキャリッジを備えている。縦置きのキャリッジは、マスクＭ及びプレートＰを垂直方向に（すなわち、縦置きに）保持し、また、投影光学系に対してマスクＭ及びプレートＰを一体的に移動させて、スキャニング（すなわち、走査）できるようにしている。この態様で垂直方向に保持されたマスクＭ及びプレートＰを有するスキャニングアライナーが、例えば、特開平８－１６２４０１に開示されている。

【０１３０】図１０を参照すると、縦置きタイプのスキャニングアライナーの全体が、固定ベース１２０Ａ上に構成されている。固定ベース１２０Ａは、固定ベース１２０Ａの４つのコーナー部とフロアとの間に介在された防振装置を備えたフロアに配置されている。サイドフレーム部１２１Ａ及び１２１Ｂが、垂直方向（Ｘ方向）に立設するように、固定ベース１２０Ａの両側部に設けられている。マスクＭが、サイドフレーム部１２１Ａの内側に設けられている。一方、プレートＰが、サイドフレーム部１２１Ｂの内側に設けられている。そのため、開口部がサイドフレーム部１２１Ａに形成されている。サイドフレーム部１２１Ａのこの開口部には、照明ユニット１２２の端部が図示のように挿入されている。照明ユニット１２２は、露光用の照明光でマスクＭを照らしマスクとプレートとのアライメントを行う光学系を備えている。

【０１３１】ガイドベース部１２３が、サイドフレーム部１２１Ａと１２１Ｂとの間でスキャニング方向（Ｙ方向）に伸長するように、固定ベース１２０Ａに設けられている。２つの真っすぐなガイドレール１２３Ａ及び１２３Ｂが、互いに平行なＹ方向に伸長するように、ガイドベース部１２３に形成されている。縦置きキャリッジ１２５が、Ｙ方向に往復移動できるように、ガイドレール１２３Ａ及び１２３Ｂ上で、流体ベアリングや磁気浮動式ベアリングによって支持されている。縦置きキャリッジ１２５は、平行に配置された２つリニアモーター１２４Ａ及び１２４Ｂによって非接触式にＹ方向に駆動される。リニアモーター１２４Ａ及び１２４Ｂは、ガイドベース部１２３に固定された固定子を備えている。

【０１３２】縦置きキャリッジ１２５は、マスク側キャリッジ部１２５Ａとプレート側キャリッジ部１２５Ｂとを備えている。マスク側キャリッジ部１２５Ａは、マスクＭを保持するためにサイドフレーム部１２１Ａの内側で垂直方向に形成されている。プレート側キャリッジ部１２５Ｂは、プレートＰを保持するためにサイドフレーム部１２１Ｂの内側で垂直方向に形成されている。マスクテーブル１２６Ａが、マスク側キャリッジ部１２５Ａに設けられている。マスクテーブル１２６Ａは、マスクＭを保持しながら、ＸＹ平面でＸ方向またはＹ方向にマスクＭをわずかに動かし、あるいは、回転（θ）方向にマスクＭをわずかに動かすことができる。さらに、マスクテーブル１２６Ａは、マスクＭを保持しながら、Ｚ方向にマスクＭをわずかに動かすことができる。他方、プレートステージ１２６Ｂが、プレート側キャリッジ部１２５Ｂに設けられている。プレートステージ１２６Ｂは、プレートＰを保持しながら、ＸＹ平面でＸ方向またはＹ方向にプレートＰをわずかに動かし、あるいは、回転（θ）方向にプレートＰをわずかに動かすことができる。さらに、マスクテーブル１２６Ａは、プレートＰを保持しながら、Ｚ方向にプレートＰをわずかに動かすことができる。

【０１３３】上述した特開平８－１６２４０１に開示されているような投影光学系ＰＬが、この実施例において使用されている。投影光学系ＰＬは、複数組の（例えば、７組の）「１Ｘ（１倍）」正立像タイプのダブルダイソン（Ｄｙｓｏｎ）系を、Ｘ方向に直交する方向に配置することによって構成されている。複数組のダブルダイソン（Ｄｙｓｏｎ）系は、ケーシング内で一体的に組合わされ且つ収容されている。ケーシングは、ＸＺ平面で見てほぼＴ字形となっている。このように構成された投影光学系ＰＬは、対向したサイドフレーム部１２１Ａ及び１２１Ｂの上側端部から垂下することによって取り付けられている。それによって、マスクＭ及びプレートＰからの所定の作動距離が維持されている。

【0134】図9に示されているように、投影光学系PLの全ケーシングにおいて、マスクM側の焦点検出系GDC’、GDL’、及びGDR’がマスクMに面するようにマスクM側に設けられており、プレートP側の焦点検出系GDC、GDL、及びGDRがプレートPに面するようにプレートP側に設けられている。先読み焦点検出系GDL、GDL’、GDR、及びGDR’によって画定された検出ポイントは、複数組のダブルダイソン（Dyson）系の投影視野に一致するように設定することができ、または、投影視野の配置にかかわりなく所定の間隔で配置することができる。

【0135】図11は、図10に示された投影光学系PLのケーシングに設けられたマスクM側の焦点検出系GDC’、GDL’、及びGDR’の検出器のレイアウトの一例の斜視図である。複数組のダブルダイソン（Dyson）系の有効な投影視野DF1、DF2、DF3、DF4、DF5・・・・・は、スキャニング方向に直交するX方向に細長い台形状の領域として設定されている。台形状の投影視野DFn（n＝1、2、3・・・）は、各隣接する対のダブルダイソン（Dyson）系の台形状の投影視野が、X方向で見て傾斜側だけ互いに重なるように配置されている。

【0136】マスクM側に設けられた投影視野DFnのみが、図11に図示されているが、プレートP側の投影視野も同じように配置されている。例えば、図11に示された投影視野DF2は、2つの凹面鏡MR2a及びMR2bを含む、図9に示されたようなダブルダイソン（Dyson）系によって画定されている。投影視野DF4は、2つの凹面鏡MR4a及びMR4bを含むダブルダイソン（Dyson）系によって画定されている。

【0137】図11に示されたように、先読み焦点検出系GDL’用の検出器GDA1’，GDB1’GDB2’・・・、GDA2’（GDA2’は図11に示されていない）と、先読み焦点検出系GDR’用の検出器GDD1’，GDE1’GDE2’・・・、GDD2’（GDD2’は図11に示されていない）とが、複数の投影視野DFnの両側（スキャニング方向に対して前側及び後ろ側）に配置されている。また、露光位置焦点検出器GDC1’及びGDC2’（検出器GDC2’は、図11に図示されていない）が、スキャニング方向に対して直交するX方向における、複数の投影視野DFnの全体のアレイ（配列）の両端に配置されている。

【0138】上述した焦点検出器の各々は、例えば、空気マイクロメータタイプの静電気ギャップセンサとなっている。上述した焦点検出器の各々は、代わりに、斜入射光タイプの焦点検出器とすることもできる。マスクMで検出を行う焦点検出器のみが、図11に図示されているが、複数の検出器が、プレートPを検出できるように、同様に、焦点検出系GDC、GDL、及びGDRに配置されている。

【0139】複数組のダブルダイソン（Dyson）系の種々の光学的な特性を調節するするための調節部KD1及びKD2が、図11に示された投影光学系PLのケーシングのサイド部に設けられている。そのため、もし、マスクM側またはプレートP側における最適な焦点面の位置が、光学的な特性調節によって図11のZ方向において変化したならば、Z方向位置を調節する機構、すなわち、各焦点検出器によって最適な焦点面として検出された機械的な（光学的な）焦点オフセットを設定する機構が設けられる。

【0140】この機構は、例えば、光路の長さを光学的に変えるように、Z方向における焦点検出器の位置を機械的に調節する機構とすることができる。または、この機構は、例えば、光路の長さを光学的に変えるように、最適な焦点位置として評価された位置を焦点検出器によってZ方向に光学的に調節する機構とすることができる。代わりに、マスクまたはプレートは、焦点誤差を表す検出信号に応じてZ方向に焦点合わせを行うことができるように、自動的に調節される。そして、オフセットが、Z方向において、その移動された位置に加えられる。

【0141】次に、本願発明にかかわる第4の実施例を、図12を参照して説明する。この実施例は、投影レンズ系PLの投影端部を、上述したように液体に浸しながら投影露光を行う装置に適用可能となっている。図12は、前記装置のうち投影レンズ系PLの端からウェハホルダーWHまでの部分の断面図である。

【0142】平坦な下面Peと凸状の上面とを備えた正レンズ素子LE1が、レンズバレル（鏡筒）の内側の、投影レンズ系PLの端に固定されている。この正レンズ素子LE1の下面Peは、レンズバレルのいちばん端の端面と同一平面となるように仕上げ加工されている。その結果、液体LQの流れの乱れが、最小限度になっている。液体LQに浸された投影レンズ系PLのレンズバレル端部に、図1に示されたものと同様な、先読み焦点検出系GDL及びGDRと露光位置焦点検出系GDCとからなる検出器が取り付けられている。その結果、それらのいちばん端の端部が、液体LQに浸されている。

【0143】真空吸引によってウェハWの裏面を引きつける複数の吸引面113が、ウェハホルダーWHの中央内側底部に形成されている。より具体的に説明すれば、吸引面113は、複数の円形帯状のランド部を備えている。円形帯状のランド部は、高さが約1mmとなっている。また、円形帯状のランド部は、ウェハWの直径方向に所定のピッチをもって、互いに同心状に形成されている。円形のランド部の中央部分に形成された溝の各々は、ウェハホルダーWHの管112に連通している。管112は、真空吸引を行う真空源に接続されている。

【0144】この実施例において、投影レンズ系PLの端にある正レンズ素子LE1の下面Peと、最適な焦点

状態におけるウェハWの上面（または、補助プレート部ＨＲＳの上面）との間の間隔（実質的な作動距離）、すなわち、投影光路が形成される液体ＬＱの厚さは、５ｍｍまたはそれ以下に設定されている。したがって、ウェハホルダーＷＨに満たされた液体ＬＱの深さＨｑは、この厚さ（５ｍｍまたはそれ以下）よりも２倍ないし数倍大きくすることができる。そして、ウェハホルダーＷＨの周囲端に垂直に形成された壁部ＬＢの高さは、約１０ｍｍないし２５ｍｍとなっている。したがって、この実施例においては、投影レンズ系ＰＬのワーキングディスタンスに対応する結像光路における液体ＬＱの厚さが減少され、その結果、ウェハホルダーＷＨに満たされた液体ＬＱの全容積はより小さくなり、液体［ＬＱ］の温度制御がより容易となっている。

【０１４５】投影光路が形成される液体ＬＱの領域において、露光光がその領域を通過するとき、照明エネルギーが吸収される。その結果、放射熱変動がに起こり易くなっている。もし、液体ＬＱの深さＨｑが小さいならば、そのような放射熱変動による温度上昇が容易に生じ、温度制御の安定性が減少するという悪影響が生じてしまう。そのような場合において、大量液体層における放射熱変動の影響を消失させるために、液体ＬＱの深さＨｑの値を実質的なワーキングディスタンスの数倍の値に設定することによって、良好な効果を得ることができる。

【０１４６】焦点検出系ＧＤＬ、ＧＤＲ、及びＧＤＣを光学的なタイプの検出系として図１２に示されたような液浸式の投影系に設けるために、ウェハWの表面や補助プレート部ＨＲＳの表面に斜めに入射する投影ビーム（光束）と、この表面から反射されたビームとが、液体ＬＱと空気との間の界面を交差するのを防止している。そのため、そのような液浸式の投影タイプのアライナーに適した焦点／チルト検出系の一例を、図１３を参照して説明する。

【０１４７】図１３は、投影レンズ系ＰＬの付近に配置された焦点検出系ＧＤＬの構成を示している。他の焦点検出系ＧＤＲ及びＧＤＣは、焦点検出系ＧＤＬが構成されているのと同様に構成されている。図１３において、図１２に示された構成要素と同じ構成要素は、同じ参照符号や参照数字によって示されている。

【０１４８】図１３を参照すると、ガラスブロックで形成されたプリズムミラー２００が、投影レンズ系ＰＬの周辺部付近に固定されている。プリズムミラー２００は下方部を備えており、その下方部は液体ＬＱに浸されている。プリズムミラー２００は、反射面２００ａ及び２００ｂを備えている。反射面２００ａ及び２００ｂの一部は、液体ＬＱに浸されている。プリズムミラー２００は、また、平坦面２００ｃ及び２００ｄを備えている。投影されるビームや反射されるビームは、平坦面２００ｃ及び２００ｄを通って、プリズムミラー２００のガラスから液体ＬＱ内に進み、あるいは、液体ＬＱからガラス内に進む。プリズムミラー２００は、また、平坦な上面を備えている。

【０１４９】マルチスリットプレート２０５が、コンデンサーレンズまたは円筒形レンズ２０３を通して、発光ダイオード（ＬＥＤ）やレーザーダイオード（ＬＤ）のような光源２０２からの（ウェハW上のレジストに対して化学線作用のない波長を有する）光りＬＫで照らされている。これによって、焦点／チルト検出用の投影ビームが形成されている。焦点検出系ＧＤＬの検出ポイント（領域）ＦＡｎ及びＦＢｎに対応する複数の透過スリットが、マルチスリットプレート２０５に形成されている。各透過スリットからの光りは、ビームスプリッター２０７によって反射され、そして、対物レンズ２０９に入射して、ウェハWの上面にスリット像を形成する結像ビームとして収束する。

【０１５０】対物レンズ２０９から出た結像ビームは、プリズムミラー２００の上端面を通ってプリズムミラー２００に入り、反射面２００ａによって通常のように反射し、平坦面２００ｃを通って液体ＬＱに入り、ウェハWの表面に斜めから入射し、これによって、ウェハWを照らしている。ウェハWによっ反射されたビームは、反対側の平坦面２００ｄを通ってプリズムミラー２００に入り、反射面２００ｂによって通常のように反射され、プリズムミラー２００の上端面を通ってプリズムミラー２００から出て進む。この反射された光ビームは、対物レンズ２１１を通過し、対物レンズ２１１の瞳孔位置に配置された反射ミラー２１３によって反射される。

【０１５１】反射ミラー２１３によって反射されたビームは、対物レンズ２１１を通って反対方向に進み、再び、プリズムミラー２００の反射面２００ｂと平坦面２００ｄを経て進み、再びウェハWを照らす。ウェハWによって再び反射された光ビームは、プリズムミラー２００の平坦面２００ｃと反射面２００ａとを経て進み、ビームスプリッター２０７を通過して、光電検出器２１５に入射する。光電検出器２１５は、マルチスリットプレート２０５に対応する光を受光する複数の素子となっている。光電検出器２１５は、それぞれ、検出ポイントＦＡｎ及びＦＢｎに関する検出信号を別々に出力する。

【０１５２】したがって、図１３に示された焦点／チルト検出系は、ウェハWによって反射された投影ビームがウェハWによって再反射される複光路系として配置されている。そのため、その焦点／チルト検出系は、単一光路系と比較して、Ｚ方向におけるウェハWの表面位置の誤差検出に関して、より高い感度を備えることができる。

【０１５３】この実施例において、ガラスブロック（プリズムミラー２００）が、焦点／チルト検出系のいちばん端に設けられており、また、そのガラスブロックは、その一部が液体ＬＱに浸されるように位置決めされてい

る。その結果、投影ビームと反射ビームとは、液体ＬＱと空気との間のいかなる界面を通過することはない。したがって、これにより、安定したビームの光路が設けられている。さらに、投影ビームまたは反射ビームが通過する液体ＬＱの光路の有効長さは、プリズムミラー２００によって減少し、それによって、Ｚ位置を測定するとき、液体ＬＱの温度変化により精度の低下を避けることができる。

【０１５４】図１及び図５に示したウェハホルダーＷＨの構造の変更例を、図１４及び図１５を参照して説明する。図１４は、液浸式の露光を行う投影露光装置に取り付けられるウェハホルダーＷＨの断面図である。この例においては、圧電素子のような微動調節可能なＺ－駆動ユニット２２０が設けられている。Ｚ－駆動ユニット２２０は、ウェハＷを支持する吸引面１１３を囲む補助プレート部ＨＲＳをわずかに移動させることができる。微動調節可能なＺ－駆動ユニット２２０は、約数十マイクロメートルのストークだけ、Ｚ方向に補助プレート部ＨＲＳを移動させる。

【０１５５】もし、ウェハホルダーＷＨの吸引面１１３上に設けられたウェハＷの表面の高さと補助プレート部ＨＲＳの表面のＺ方向における高さとの間の差が、許容差よりも大きいならば、このＺ－駆動ユニット２２０を使用して、補助プレート部ＨＲＳの表面の高さを補正して、前記許容差よりも小さい値に前記差を減少させることができる。

【０１５６】図５を参照して上述したように、補助プレート部ＨＲＳの表面は、ウェハＷの周辺部のショット領域ＳＡ１が露光されるとき、ウェハＷの外側に設けられた焦点検出ポイントＦＡ１（または、ＦＡ２）、ＦＣ１（またはＦＣ２）、及びＦＤ１（またはＦＤ２）用の代替的な検出表面として機能している。しかしながら、ウェハＷの内側のショット領域ＳＡ２（図５参照）が露光されるとき、これらの焦点検出ポイントはウェハＷ上に位置決めされる。そのため、補助プレート部ＨＲＳの表面及びウェハＷの表面の一方の上に独占的に位置決めされない検出ポイントを有する焦点検出器ＧＤＡ１、ＧＤＡ２、ＧＤＣ１、ＧＤＣ２、ＧＤＤ１、及びＧＤＤ２は、これらの表面の各々の上でＺ位置が正確に測定されなければならない。すなわち、補助プレート部ＨＲＳの表面及びウェハＷの表面のＺ方向における位置が、各焦点検出器ＧＤＡｎ、ＧＤＣｎ、及びＧＤＤｎの線形焦点測定範囲内に位置している必要がある。

【０１５７】例えば、もし、焦点検出器の線形焦点測定範囲が±１０マイクロメートルならば、補助プレート部ＨＲＳの表面及びウェハＷの表面のＺ位置ずれは、数マイクロメートルの範囲内に制限される。しかしながら、ウェハの厚さは、ＳＥＭＩ（半導体製造装置材料協会）標準によって決定された公差で変化する。使用可能な全てのウェハの厚さを数マイクロメートルの範囲内に制限することは困難である。

【０１５８】そのため、露光される前に、ウェハＷが図１４に示されたウェハホルダーＷＨに引きつけられたとき、ウェハＷ表面の適切な部分のＺ位置（例えば、周辺ショット領域の中央部分）と補助プレート部ＨＲＳの表面のＺ位置との間の差が、焦点検出系（ＧＤＬ、ＧＲＤ、ＧＤＣ）の１つを使用することによって測定され、その後、露光が行われる。もし、その差が許容範囲（例えば、数マイクロメートル）を越えているならば、図１４に示された微動調節可能なＺ－駆動ユニット２２０を制御することによってその差が許容範囲内に収まるように、補助プレート部ＨＲＳの高さが調節される。図１４に示されたウェハホルダーＷＨが液体ＬＱで満たされることから、微動調節可能なＺ－駆動ユニット２２０は防水処理されており、これによって、液体の当該ユニットへの入り込みが防止されている。

【０１５９】次に、図１５に示された構成を説明する。図１５は、大気中でウェハを露光するのに適した、ウェハホルダーＷＨとＺＬステージ３０とを備えた構造の変更例の断面図である。図１４に示された構成要素に対応する構成要素が、同じ参照符号や参照数字によって示されている。図１５を参照すると、ウェハホルダーＷＨは、チャックとして構成されている。ウェハＷを支持するための吸引面１１３のみがウェハホルダーＷＨに形成されている。ウェハホルダーＷＨはＺＬステージ３０に固定されている。

【０１６０】補助プレート部ＨＲＳが、微動調節可能なＺ－駆動ユニット２２０によってＺＬステージ３０に取り付けられている。Ｚ－駆動ユニット２２０は、補助プレート部ＨＲＳとＺＬステージ３０との間に介在されている。Ｚ方向とチルト運動方向にＺＬステージ３０を駆動する３つのＺ－アクチュエーター３２Ａ、３２Ｃ、及び３２Ｂ（３２Ｂは図１５に図示せず）の各作用ポイントＰＶが、ウェハホルダーＷＨのウェハ取付面（吸引面１１３）と実質的に同じ高さにあるＺＬステージ３０の周辺部のポイントに設定されている。

【０１６１】また、図１５に示されているように、補助プレート部ＨＲＳの高さは、図１４に示されたのと同じ方法で、微動調節可能なＺ－駆動ユニット２２０を使用することによって、ウェハＷの上面の高さに調節される。作用ポイントＰＶの高さは、ウェハ表面と同じ高さに設定される。図１５に示されたＺＬステージ３０の構造とＺ－アクチュエーター３２Ａ、３２Ｃ、及び３２Ｂの構造は、図１に示されたアライナーにも適用可能である。また、図１４のウェハホルダーＷＨを図１５のＺＬステージ３０に取り付けることにより、液浸式の投影露光装置や液浸式の投影露光方法に適した焦点合わせ及びチルト運動ステージを形成することができる。

【０１６２】本願発明は、露光装置への適用に関して説明した。しかしながら、上述した実施例は、本願発明の

範囲を離れることなしに、種々の方法で変更することができる。例えば、大気中で投影露光を行うアライナーの場合に、焦点検出系GDL、GDR、及びGDCは、静電容量タイプのギャップセンサや空気マイクロメータタイプのギャップセンサを備えることができる。また、本願発明は、例えば、露光光として、水銀放電ランプから放出されるg線（463nm）またはi線（365nm）やKrFエキシマーレーザーから放出されるパルス光（248nm）を使用する、ステップアンドリピートタイプ、ステップアンドスキャンタイプ、及び「1X（1倍）」スキャニングタイプのどのタイプの投影アライナーにも適用可能である。

【0163】本願発明によれば、投影アライナーに取り付けられた投影光学系のワーキングディスタンスがきわめて小さい値に設定されている一方で、露光位置での正確な焦点合わせやチルト制御を実現することができ、それによって、投影光学系の光学設計における種々の収差の補正やディストーションの補正が容易となり、像面の近くに位置決めされた透明な光学素子のサイズを特に小さくできる。

【0164】本願発明の上述した実施例にかかわる焦点合わせ／チルト制御系の各々は、一定のタイプの投影露光装置に適用可能である。しかしながら、本願発明は、また、ビーム加工（製造）装置、描画装置、及び検査装置などのための焦点／チルト検出系にも適用可能であり、半導体製造に限定されるものではない。これらのビーム加工装置、描画装置、及び検査装置には、光学的または電気光学的な対物レンズ系が設けられている。本願発明は、基板、被検物、または被加工物上の焦点を検出するための焦点検出系として、前記光学的または電気光学的な対物レンズ系に適用できる。

【0165】図16は、レーザービームや電子ビームで被加工物を加工する装置あるいは被加工物上にパターンを描画する装置の対物レンズ光学系に適用された焦点検出系の構成を示している。図17は、図16に示された焦点検出系の検出ポイントの平坦なレイアウトを示している。

【0166】図16を参照すると、加工または描画用のビームLBWが、スキャニングミラー300によって、一次元的にまたは二次元的に偏向させられ、そして、レンズ系301、固定ミラー302、及びレンズ系303を通って、ビームスプリッター304に入射する。ビームLBWは、ビームスプリッター304によって反射され、わずかなワーキングディスタンスを有する高解像度の対物レンズ系305に入射する。ビームLBWは、対物レンズ系305によって、被加工物WP上の、所定の形状（例えば、可変長方形形状）を有する小さなスポットに集光される。

【0167】被加工物WPは、図14または図15に示されたようなものと同じウェハホルダーWHに引きつけられ、固定されている。補助プレート部HRSは、被加工物WPの周囲でウェハホルダーWHに一体的に取り付けられている。ウェハホルダーWHは、図示されていないXYZ－ステージに固定されており、このXYZ－ステージは、水平方向や図16で見て紙面に対して直交する方向に二次元的に移動可能となっている。ウェハホルダーWHは、また、垂直方向（Z－方向）にわずかに移動して、焦点合わせができるようになっている。

【0168】図16に示された装置には、また、観測、アライメント、または照準合わせ用の照明光を発するための光ファイバー310と、上記ビームスプリッター304に照明光を案内するビームスプリッター311及びレンズ系312と、受光装置（例えば、フォトマルチプライヤー、撮像管、CCDなど）314とが設けられている。受光装置314は、被加工物WPから、対物レンズ系305を通して得られた、反射光や散乱し回折した光などを光電的に検出できるようになっている。

【0169】先読み焦点検出系GDL及びGDRと、加工位置焦点検出系GDCとが、対物レンズ系305の周囲に設けられている。図17は、対物レンズ系305の視野305Aと、視野305Aの周辺に配置された焦点検出系の検出ポイントの平坦なレイアウトを示している。便宜上、視野305Aの中心は、XY座標系の原点に設定されている。視野305Aの長方形領域は、スキャニングミラー300によって引き起こされるビームLBWの偏向により、該ビームLBWのスポットがスキャン（すなわち、走査）する範囲を示している。

【0170】焦点検出器GDA1、GDBn、及びGDA2が、対物レンズ系の視野305Aの左側サイド上に配置されており、その結果、検出ポイントFA1、FB1、FB2、FB3、及びFA2が、Y軸に平行な列となるように設定されている。また、焦点検出器GDD1、GDEn、及びGDD2が、視野305Aの右側サイド上に配置されており、その結果、検出ポイントFD1、FE1、FE2、FE3、及びFD2が、Y軸に平行な列となるように設定されている。

【0171】一方、焦点検出器GDC1が視野305Aの上方に設けられている。そして、3つの検出ポイントFD1a、FD1b、及びFD1cが、2つの検出ポイントFA1及びFD1を通りX軸に平行なライン上に配置されるように、焦点検出器GDC1は設定されている。他方、焦点検出器GDC2が視野305Aの下方に設けられている。そして、3つの検出ポイントFD2a、FD2b、及びFD2cが、2つの検出ポイントFA2及びFD2を通りX軸に平行なライン上に配置されるように、焦点検出器GDC2は設定されている。この実施例において、被加工物WPがX方向に移動する間、一組の焦点検出器GDA1、GDBn、及びGDA2と、一組の焦点検出器GDD1、GDEn、及びGDD2とが、焦点先読み機能として選択される。一方、被加

工物ＷＰがＹ方向に移動する間、焦点先読み機能は、一組の焦点検出器ＧＤＡ１、ＧＤＣ１、及びＧＤＤ１と、一組の焦点検出器ＧＤＡ２、ＧＤＣ２、及びＧＤＤ２とを選択することによって達成される。この実施例は、焦点検出器ＧＤＢｎ、ＧＤＣ１、ＧＤＣ２、及びＧＤＥｎの検出ポイントを変えることにより、加工位置の焦点を検出できるように構成されている。例えば、被加工物ＷＰが、図１６の左側サイドから右側サイドにかけてＸ軸に沿って移動するとき、検出ポイントＦＡ１、ＦＢ１、ＦＢ２、ＦＢ３、及びＦＡ２を使用して先読みを行いながら、検出ポイントＦＤ１ａ及びＦＤ２ａと、検出ポイントＦＤ１ｂ及びＦＤ２ｂと、検出ポイントＦＤ１ｃ及びＦＤ２ｃとからなる３対の検出ポイントのうち一対の検出ポイントを、加工位置の焦点を検出するために選択することができる。

【０１７２】この構成は、下記の効果を達成できるように意図されている。すなわち、加工用または描画用の光ビームＬＢＷのスポット位置が、スキャニング範囲３０５Ｂで変化する。そのため、例えば、光ビームＬＢＷのスポットが、図１７に示されるようなスキャニング範囲３０５Ｂの最も左端に位置決めされたとき、２つの検出ポイントＦＤ１ａ及びＦＤ２ａを選択して、加工位置の焦点検出を行うことができる。光ビームＬＢＷのスポットが、スキャニング範囲３０５Ｂの最も右端に位置決めされたとき、２つの検出ポイントＦＤ１ｃ及びＦＤ２ｃを選択して、加工位置の焦点検出を行うことができる。

【０１７３】この方法において、焦点制御やチルト制御の再現性と精度とが改善される。図１６に示されたホルダーＷＨは、ＸＹステージ上で、焦点合わせ（Ｚ）方向とチルト運動方向にわずかに移動する。この移動を行うための駆動系と制御系として、実質的な変更を行うことなしに図４に示されたものを使用できる。

【０１７４】上述したように、図１６及び図１７に示された焦点検出系は、被加工物ＷＰの二次元運動方向の各々において焦点の先読み検出ができるように、また、加工位置に関する焦点検出ポイントが、視野３０５Ａにおけるビームスポットの位置に応じて選択できるように構成されている。その結果、被加工物ＷＰの周辺部でさえも、正確に焦点合わせがなされた状態で精密に加工（結像）され、または、パターン結像が、そのような状態で被加工物ＷＰ上に行われる。

【０１７５】本願発明の焦点／チルト検出系が適用可能な検査装置の概要を、図１８を参照して説明する。図１８は、フォトリソグラフィー用のマスクやレチクルに写されたパターンの欠陥、あるいは、基板に形成された、半導体装置や液晶ディスプレー装置の回路パターンの欠陥を光学的に検査する装置の例を示している。

【０１７６】最近、対物レンズ光学系を通して被検査パターンを拡大することによって、また、ＣＣＤカメラなどによりその拡大された被検査パターンの拡大像を形成することによって、さらに、そのような像から得られた像信号を分析することによって、被検物（基板）に形成された被検査パターンの品質を検査したり異質の粒子などの異物や損傷の存在及び非存在を検査する技術が、この種の検査装置に積極的に導入されている。

【０１７７】そのような場合、被検査パターンの像が正確に拡大されるように、精度を改善することが重要である。そのため、解像度が高く視野サイズの大きい、しかも、最小限の収差とディストーションで像を形成できる対物レンズ系が要求される。そのような対物レンズ系は、当然に、ワーキングディスタンスが小さくなっており、また、焦点検出が対物レンズ系を通して行われるように、通常、スルーザレンズ（ＴＴＬ）タイプとして設計される。しかしながら、ＴＴＬ光学焦点検出系は、検出感度（被検物を焦点合わせする際の誤差に対する検出信号の変化量）を制限する問題を伴ってしまう。なぜなら、対物レンズ系の開口数（ＮＡ）が制限されるからである。

【０１７８】もし、ＴＴＬ焦点検出系が、検査用の照明光の波長と異なる波長を有する光りを使用するように形成されているならば、対物レンズ系の光学的設計を行う場合、検査用の照明光の波長帯域と焦点検出照明光の波長帯域とを考慮して、収差を補正しなければならない。そのような場合、レンズは、検査用の照明光に対して最適に設計できるとは限らない。

【０１７９】そのとき、図１８に示されているように、複数組の焦点検出系ＧＤＣ、ＧＤＬ、及びＧＤＲが、対物レンズ３３０の周囲に設けられ、これにより、図１６及び図１７に示された焦点検出系と同じ方法で検査を行うことができるようになっている。検査すべき被検物ＷＰは、例えば、パターンＰａが下面に形成されたマスクとなっている。被検物ＷＰは、その周辺端で、二次元方向に移動可能なフレーム状のステージ３３１により、支持されている。ステージ３３１は開口部を備えている。対物レンズ３３０は、上側を向いた状態で、ステージ３３１の移動を案内するベース部材３３２に取り付けられている。パターンＰａの局部領域の拡大像は、ビームスプリッター３３４とレンズ系３３５とを通って、撮像装置３３６の像面に結像する。

【０１８０】被検物ＷＰの反対側には、照明光学系のコンデンサーレンズ３３８が、対物レンズ３３０の軸ＡＸと同軸に配置されている。光ファイバー３４０からの照明光は、コンデンサーレンズ３４１と、照明視野絞り３４２と、レンズ系３４３とを通って進み、コンデンサーレンズ３３８に入射するようになっている。それによって、被検物ＷＰのうち対物レンズ３３０の視野に対応する領域が、一様な照度で照らされる。

【０１８１】上述した構成において、焦点検出系ＧＤＣ、ＧＤＬ及びＧＤＲは、上側でパターンＰａに面するように、対物レンズ３３０と一緒にベース部材３３２に

取り付けられている。複数の焦点検出器（複数の検出ポイント）が、先読み可能な焦点検出系ＧＤＬ及びＧＤＲに設けられている。一方、少なくとも一対の焦点検出器が、検査ポイントで検出可能な焦点検出系ＧＤＣに設けられている。

【０１８２】また、図１８に示した焦点検出系において、ステージ３３１上の被検物ＷＰは、光軸ＡＸに沿って垂直方向に移動できるようにしてもよく、または、図４に示されたような制御回路を使用することによって焦点検出器により検出された焦点位置情報に基づいてチルトできるようにしてもよい。しかしながら、図１８に示された検査装置においては、撮像装置３３６によって結像されたパターンＰａの拡大像の品質が高くなるという効果のみが得られれば十分である。そのため、被検物ＷＰを垂直方向に移動させる手段の代わりに、対物レンズ３３０またはレンズ系３３５を光軸ＡＸに沿ってわずかに移動させるための焦点調整装置３５２Ａまたは３５２Ｂを設けることができる。

【０１８３】被検物ＷＰとして設けられたマスクパターンＰａを下方に向くように位置決めする検査装置を、図１８の例を参照して説明する。言うまでもなく、この実施例は、パターンＰａを上に向け対物レンズを下に向けた検査装置にも直接的に適用できる。図１８に示された装置において、パターンＰａの伝達された像は、同軸に設けられた透過照明系によって検査される。

【０１８４】しかしながら、前記透過照明系は、同軸の反射照明光がビームスプリッター３３４を通して図１８の矢印３５０の方向に導入されるように、変更することができる。そのような場合、撮像装置３３６によって受光された拡大像は、パターンＰａからの反射光を結像することによって形成される。

【０１８５】さらに、他の方法を用いることもできる。その方法においては、所望の形状を有する透過部を備えた空間フィルターが、照明光学系の光路またはその結像光学系に形成されたフーリエ変換平面の位置に取り外し可能に設けられている。これにより、パターンＰａの明視野像または暗視野像が、撮像装置３３６に選択的に結像できるようになっている。

【０１８６】この開示は例示されたものであり、本願発明が、この開示に限定されるものではない。さらに、この開示の観点から当業者にとって別の変更例は明らかであり、かかる変更例は、添付した請求項の範囲に含まれる。

【図面の簡単な説明】

【図１】図1は、本願発明の第１の実施例におけるスキャンニング投影露光装置（アライナー）を示す線図である。

【図２】図2は、スキャンニングシーケンスを説明するための略斜視図である。

【図３】図3は、図１に示された投影レンズ系の端の付近に設けられた焦点検出系の配置の略斜視図である。

【図４】図4は、図１に示されたＡＦコントロールユニット回路構造の回路ブロック線図である。

【図５】図5は、図１に示された装置のウェハ上における、投影視野と焦点合わせ用のセンサとの間の位置関係の平面図である。

【図６】図６Ａは、図１に示された装置の焦点合わせ作用とチルト作用との線図である。図６Ｂは、図1に示された装置の焦点合わせ作用とチルト作用との線図である。図6Ｃは、図1に示された装置の焦点合わせ作用とチルト作用との線図である。図６Ｄは、図１に示された装置の焦点合わせ作用とチルト作用との線図である。

【図7】図7は、本願発明の第２実施例における焦点／チルト検出系の検出領域のレイアウトの平面図である。

【図8】図8は、図7に示された焦点／チルト検出系の変更例のレイアウトの側面図である。

【図9】図9は、本願発明がスキャニング露光装置（スキャニングアライナー）に適用される、本願発明の第３実施例の略線図である。

【図１０】図１０は、図9に示されたスキャニングアライナーに適用される縦置きキャリッジの斜示図である。

【図１１】図１１は、図9に示された投影アライナーに設けられた、投影光学系と焦点検出系との斜視図である。

【図１２】図１２は、本願発明の構成が液浸式投影露光装置に適用された場合における本願発明の第４の実施例の断面図である。

【図１３】図１３は、液浸式投影露光装置に適した焦点／チルト検出系の光路レイアウトの例を示す線図である。

【図１４】図１４は、ウェハホルダーの変更例の断面図である。

【図１５】図１５は、ウェハホルダーの変更例の断面図である。

【図１６】図１６は、本願発明の焦点検出センサが適用される、製造装置、結像装置、または描画装置の１例を示す線図である。

【図１７】図１７は、図１６に示された装置に適用される焦点検出系の典型的なレイアウトを示す平面図である。

【図１８】図１８は、本願発明の焦点／チルト検出系が適用される典型的な検査装置の構造を概略的に示している線図である。

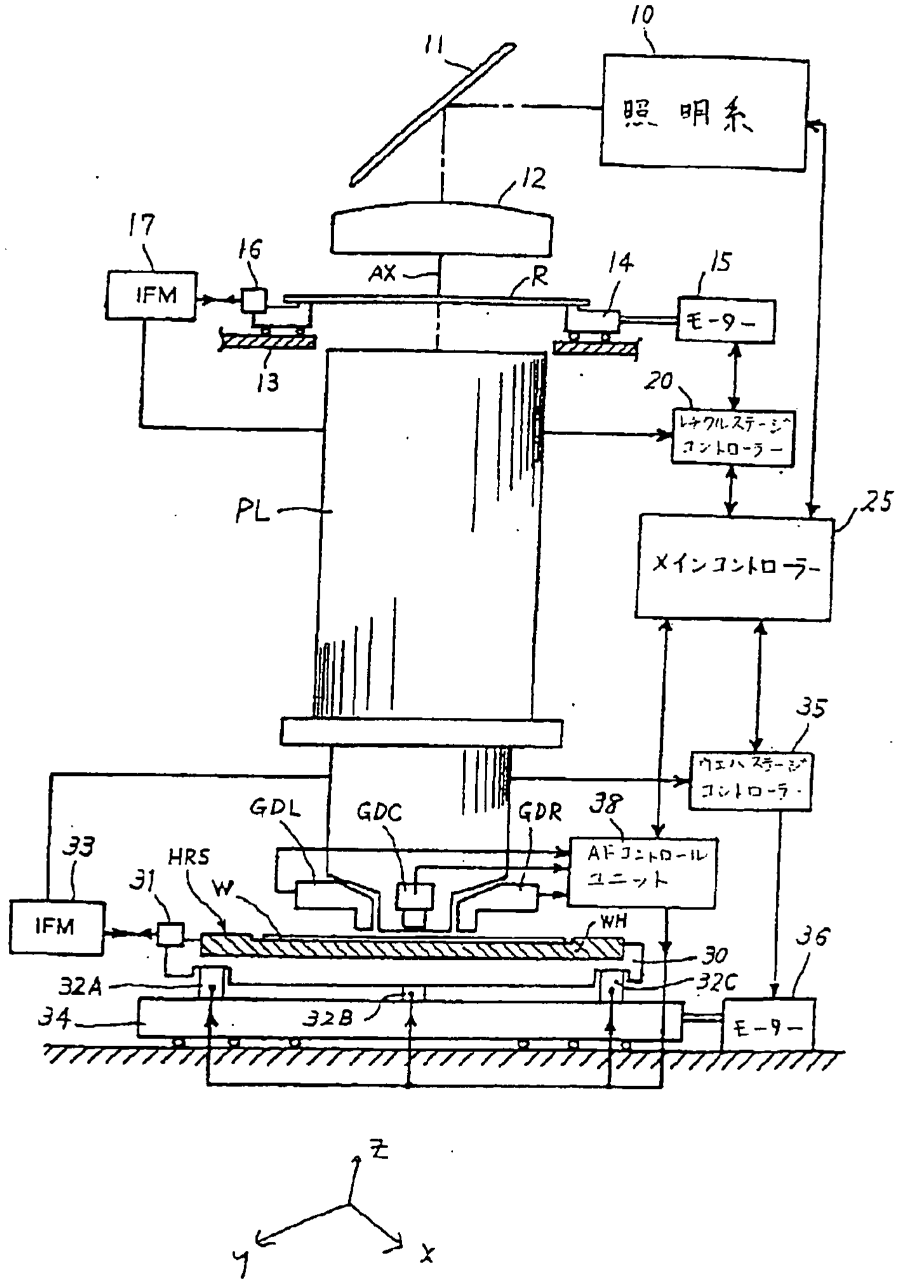
【符号の説明】

１０　照明系　　１１　ミラー
１２　集光レンズ系　　１３　柱状構造体
１４　レチクルステージ　　１５　モーター
１６　移動鏡　　１７　レーザー干渉計システム
２０　レチクルステージコントローラー

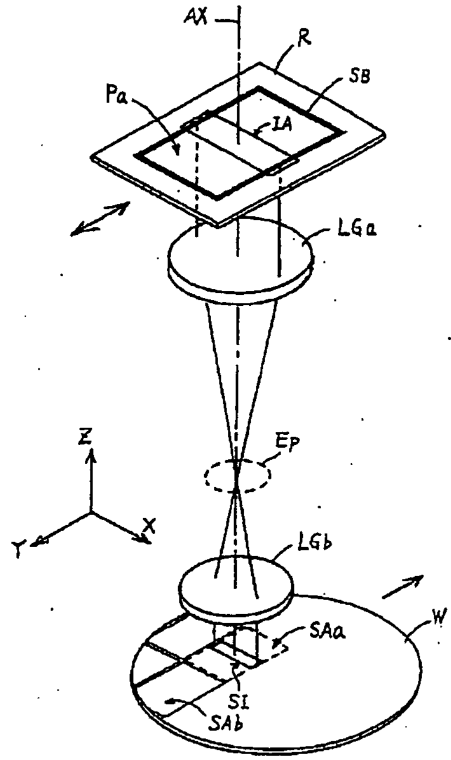
25　メインコントローラ　30　ZLステージ
31　移動鏡　32A　Z－アクチュエーター
32B　Z－アクチュエーター　32C　Z－アクチュエーター
33　レーザー干渉計　34　XYステージ
35　ウェハステージコントローラー
36　駆動モーター　52　位置監視回路
54　第1の計算器　56　第2の計算及び記憶回路
58　第3の計算及び駆動回路　80A　照明光学系
80B　受光装置　81A　マルチスリットプレート
81B　受光スリットプレート　82A　レンズ系
82B　レンズ系　83A　反射鏡
83B　反射鏡　84A　対物レンズ
84B　対物レンズ　85A　プリズム
85B　プリズム　100　キャリッジ
112　管　113　吸引面
120A　固定ベース　121A　サイドフーム部
121B　サイドフーム部　122　照明ユニット
123　ガイドベース部　123A　ガイドレール
123B　ガイドレール　125A　マスク側キャリッジ部
125B　プレート側キャリッジ部　126A　マスクテーブルA
126B　プレートステージ　200　プリズムミラー
200a　反射面　200b　反射面
200c　平坦面　200d　平坦面
202　光源　205　マルチスリットプレート
207　ビームスプリッター　209　対物レンズ
211　対物レンズ　213　反射ミラー
215　光電検出器　220　Z－駆動ユニット
300　スキャニングミラー　301　レンズ系
302　固定ミラー　303　レンズ系
304　ビームスプリッター　305　対物レンズ系
310　光ファイバー　311　ビームスプリッター
312　レンズ系　314　受光装置
330　対物レンズ　331　ステージ
332　ベース部材　335　レンズ系
334　ビームスプリッター　336　撮像装置
341　コンデンサーレンズ　342　照明視野絞り
343　レンズ系　338　コンデンサーレンズ
352A　調整装置　352B　調整装置
AX　光軸　Cp　像視野
Ep　射出瞳　FA1　検出ポイント
FB1　検出ポイント　FB2　検出ポイント
FB3　検出ポイント　FA2　検出ポイント
FC1　検出ポイント　FC2　検出ポイント
GDL　焦点検出系　GDR　焦点検出系
GDA1　検出器　GDA2　検出器
GDB1　検出器　GDB2　検出器
GDB3　検出器　GDD1　検出器
GDD2　検出器　GDE1　検出器
GDE2　検出器　GDE3　検出器
GDC　焦点検出系　GDC1　検出器
GDC2　検出器　HRS　補助プレート部
IA　パルス照明光　IL　照明光
ILF　照明光　LGa　前方グループレンズ系
LGb　後方グループレンズ系　LLa　直線
LLb　直線　LLc　延長線
LE1　正レンズ素子　LQ　液体
LB　壁部　LK　光り
LBW　ビーム　M　マスク
MR1　凹面鏡　MR2　凹面鏡
MR2a　凹面鏡　MR2b　凹面鏡
NT　切欠き　P　プレート
Pa　回路パターン領域　Pe　平坦な下面
PL　投影レンズ系　PM1　プリズムミラー
PM2　プリズムミラー　PM3　プリズムミラー
PM4　プリズムミラー　PV　作用ポイント

Ｒ　レチクル　　　　　　　　ＲＳｆ　結像光線　　　ＳＢ　遮蔽帯　　　　　　ＳＩ　投影像
ＳＡａ　ショット領域　　　　ＳＡｂ　ショット　　　ＳＬｆ　結像光線　　　　Ｗ　ウェハ
領域　　　　　　　　　　　　　　　　　　　　　　　ＷＨ　ウェハホルダー

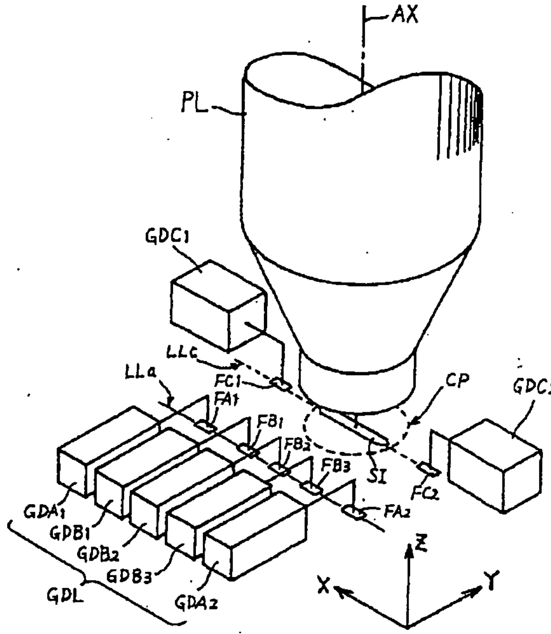
【図１】



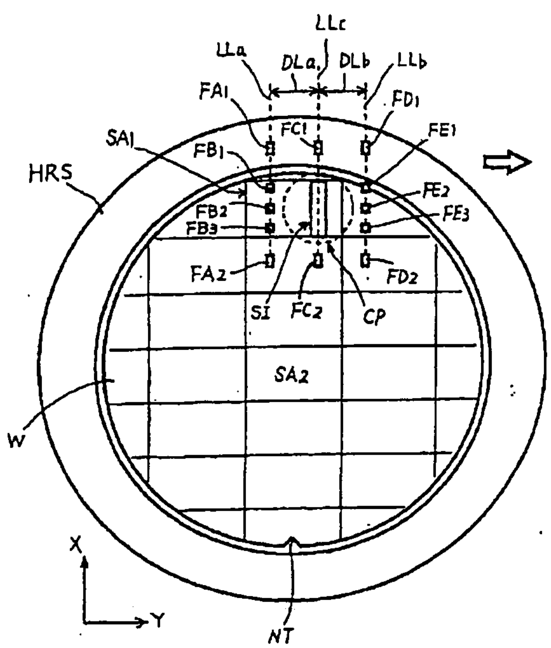
【図2】


AX
R
SB
Pa
IA
LGa
Z
Ep
Y
X
LGb
SAa
W
SI
SAb

【図3】


AX
PL
GDC1
LLc
LLa
FC1
FA1
CP
GDC2
FB1
FB2
FB3
SI
FC2
FA2
GDA1
GDB1
GDB2
GDB3
GDA2
GDL
X
Z
Y

【図5】


LLc
LLa
DLa
DLb
LLb
FA1
FD1
FC1
FE1
SA1
FB1
HRS
FB2
FE2
FB3
FE3
FA2
FD2
SI
FC2
CP
SA2
W
X
Y
NT

【図6】

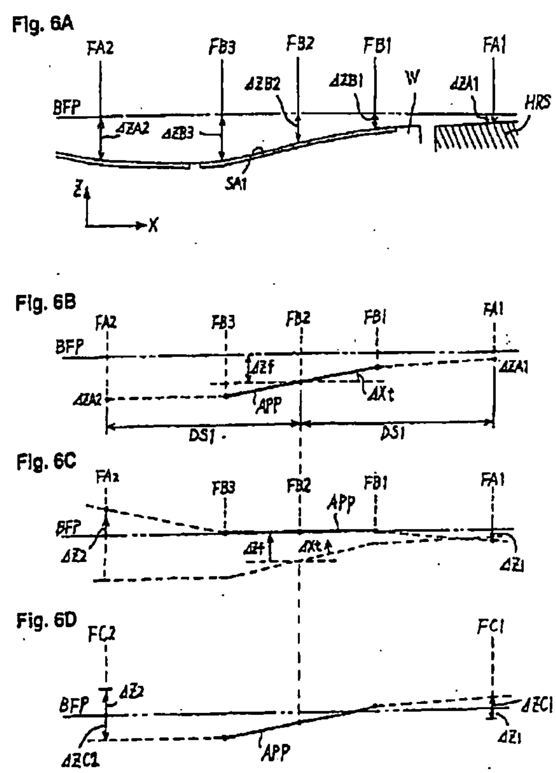
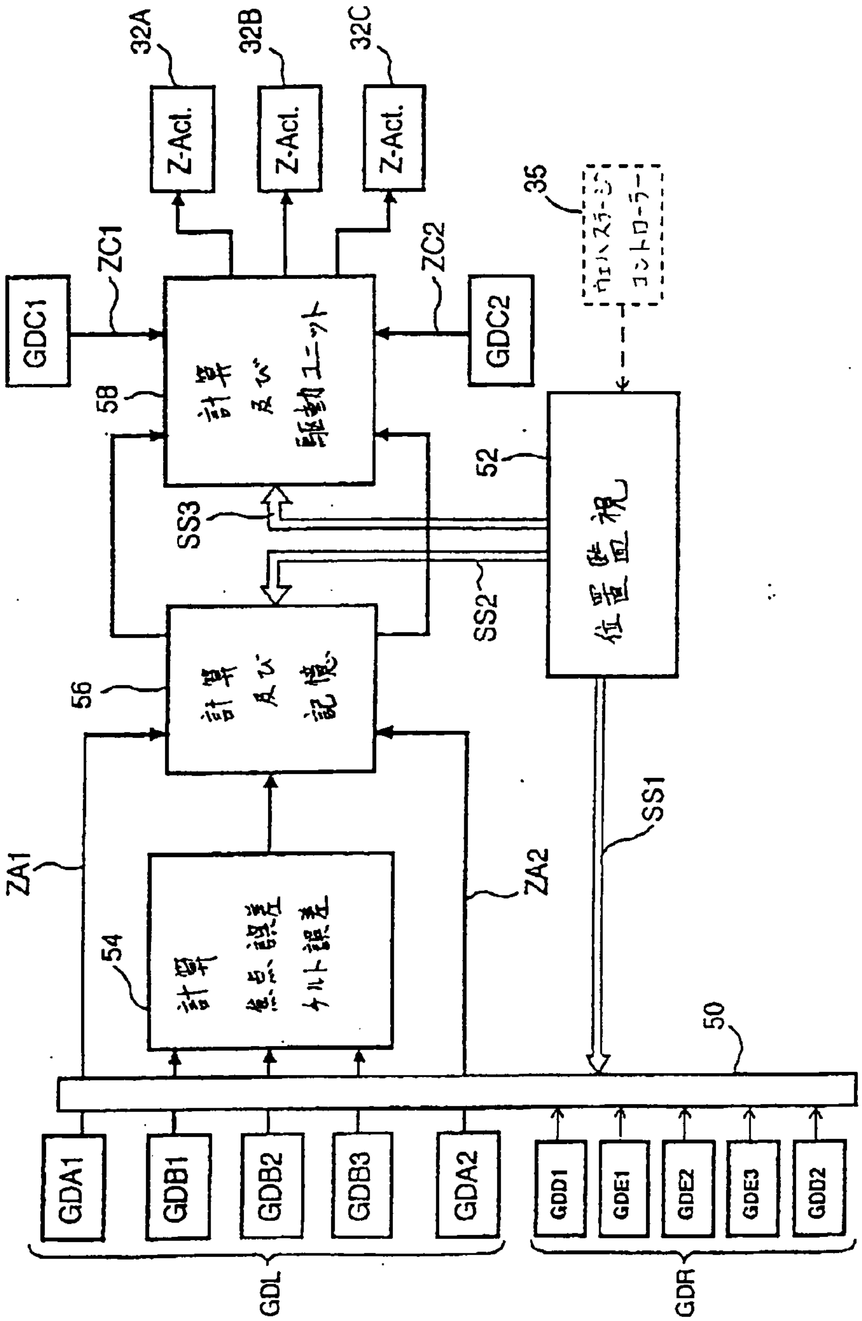
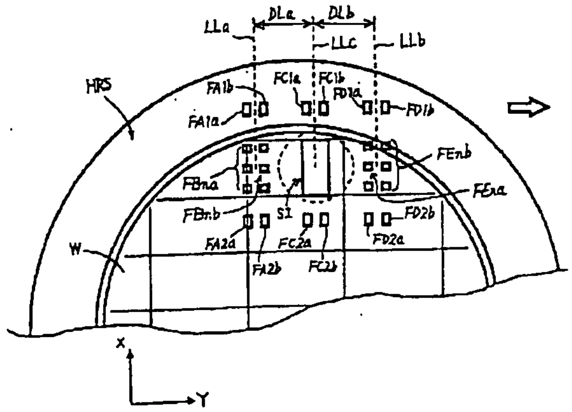


Fig. 6A
FA2
FB3
FB2
FB1
FA1
ΔZB2
ΔZB1
W
ΔZA1
HRS
BFP
ΔZA2
ΔZB3
SA1
Z
X
Fig. 6B
APP
ΔZf
ΔXt
ΔZA1
ΔZA2
DS1
Fig. 6C
FA2
ΔZ2
ΔZ1
Fig. 6D
FC2
FC1
ΔZC1
ΔZC2

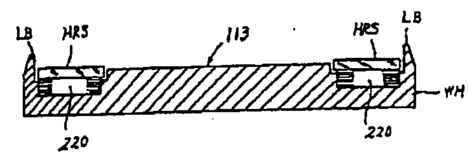
【図4】


32A
32B
32C
Z-Acl.
Z-Acl.
Z-Acl.
35
ウェハステージ
コントローラー
GDC1
ZC1
計算及び駆動ユニット
5B
ZC2
GDC2
52
位置監視
SS3
SS2
56
計算及び記憶
ZA1
54
計算
焦点誤差
チルト誤差
ZA2
SS1
50
GDA1
GDB1
GDB2
GDB3
GDA2
GDD1
GDE1
GDE2
GDE3
GDD2
GDL
GDR

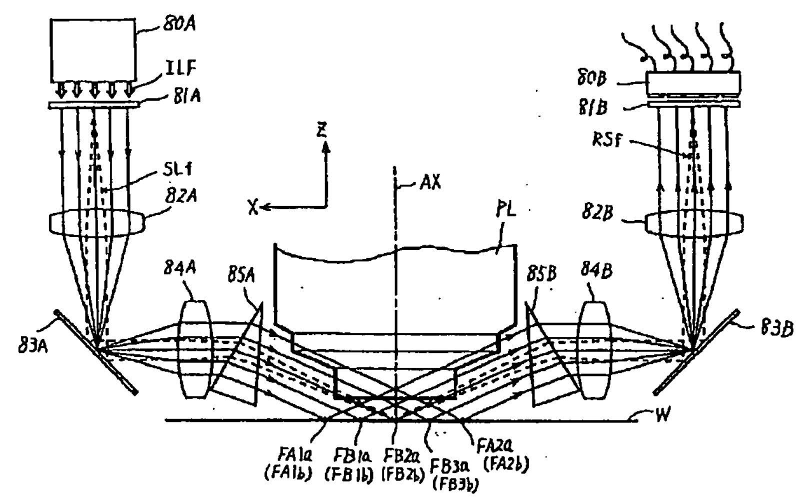
【図7】



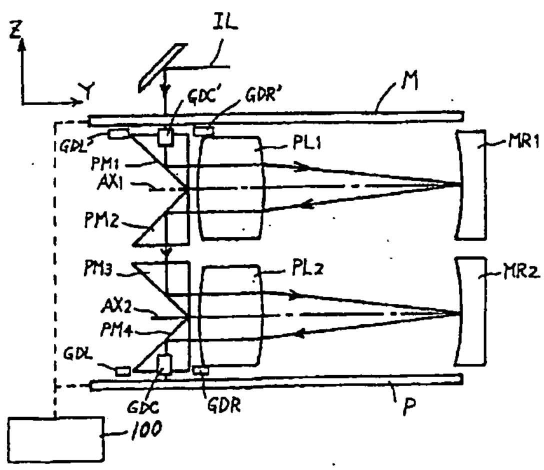
【図14】



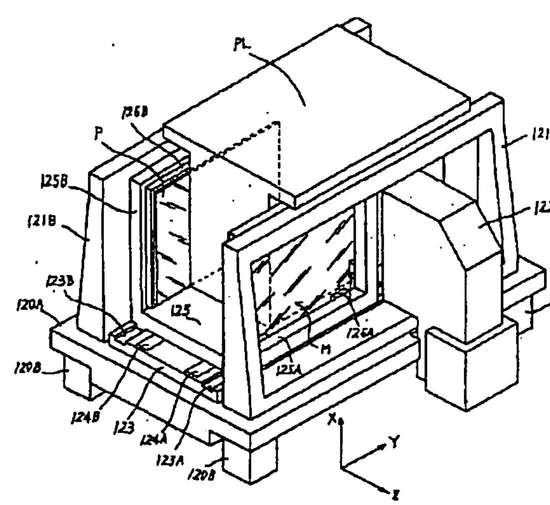
【図8】



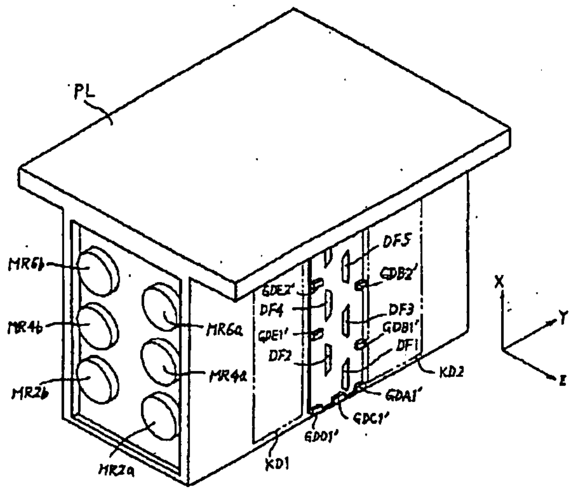
【図9】



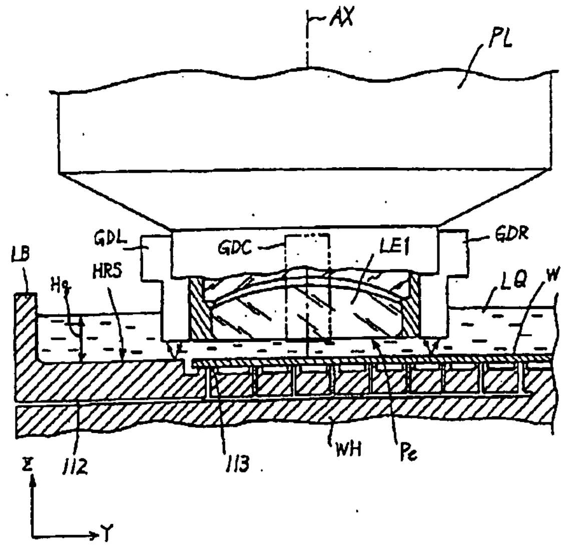
【図10】



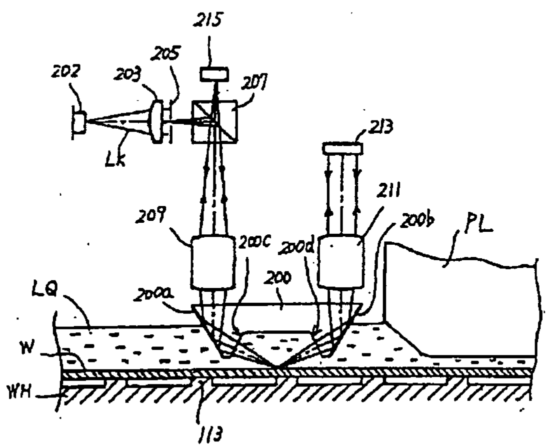
【図11】



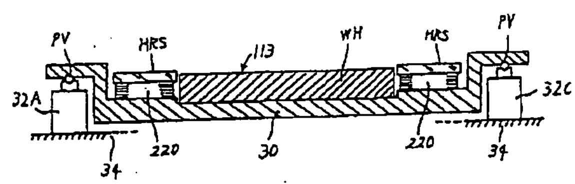
【図12】



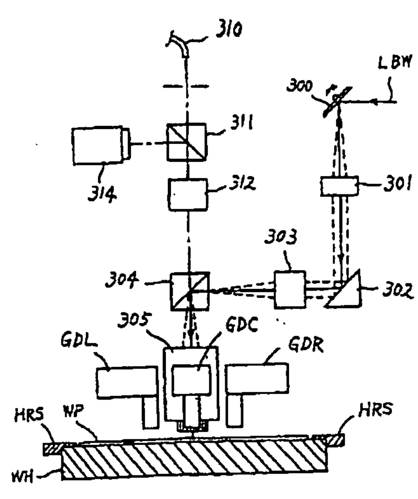
【図13】



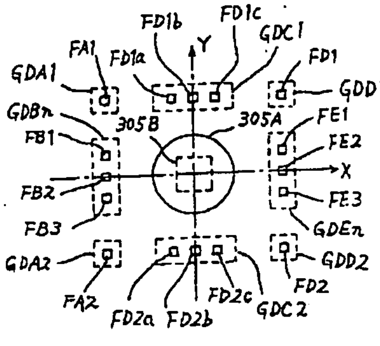
【図15】



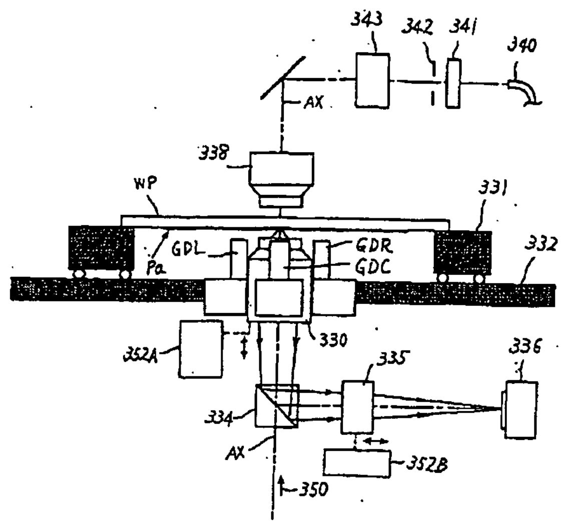
【図16】



【図17】



【図18】


343
342
341
340
AX
338
WP
331
332
GDL
GDR
GDC
Pa
330
352A
335
336
334
AX
352B
350

【外国語明細書】

1. **Title of Invention**

FOCUSING AND TILTING ADJUSTMENT SYSTEM
FOR LITHOGRAPHY ALIGNER,
MANUFACTURING APPARATUS OR INSPECTION APPARATUS

2. **Claims**

1. A scanning exposure apparatus comprising:

(a) an imaging system for projecting an image of a pattern of a mask onto a substrate at an imaging field;

(b) a scanning mechanism for moving the mask and the substrate in a scanning direction relative to said imaging system;

(c) an adjusting system for adjusting a focus of the projected image on the substrate;

(d) a first detection system having a detection area at a first position located outside the imaging field of said imaging system and spaced apart from the imaging field in the scanning direction, said first detection system detecting the position of a principal surface of the substrate in a Z-direction;

(e) a second detection system having a detection area at a second position located outside the imaging field of said imaging system and spaced apart from said first position in a direction intersecting the scanning direction, said second detection system detecting the position of the principal surface of the substrate in the Z-direction;

(f) a third detection system having a detection area at a third position located outside the imaging field of said imaging system, spaced apart from the imaging field in a direction intersecting the scanning direction and also spaced apart from said second position in the scanning direction, said third detection system detecting the position of the principal surface of the substrate in the Z-direction;

(g) a calculator coupled to said first and

second detection systems and calculating a deviation between the first Z-position detected by said first detection system and a target Z-position and storing the second Z-position detected by said second detection system at the time of detection by said first detection system; and

(h) a controller coupled to said adjusting system and to said calculator and to said third detection system and controlling said adjusting system on the basis of the calculated deviation, the stored second Z-position and the third Z-position detected by said third detection system when the area on the substrate corresponding to the detection area of said first detection system is positioned in the imaging field of said imaging system by movement of said scanning mechanism.

2. An exposure apparatus according to Claim 1, wherein said scanning mechanism includes a mask stage for holding the mask, a substrate stage for holding the substrate, and a synchronizing drive system for moving said mask stage and said substrate stage at a speed ratio corresponding to a projection magnification of said imaging system.

3. An exposure apparatus according to Claim 2, wherein said substrate stage includes an attraction portion for attracting a reverse surface of the substrate, and an auxiliary plate portion surrounding the substrate at a height approximately equal to the principal surface of the substrate when the substrate is supported on said attraction portion.

4. An exposure apparatus according to Claim 3, wherein said second detection system and said third

detection system are arranged to detect the position of a surface of said auxiliary plate portion in the Z-direction by at least one of the detection areas when a shot area of the substrate to be exposed by the pattern of the mask is at a peripheral portion of the substrate.

5. An exposure apparatus according to Claim 4, wherein each of said first, second and third detection systems generates a Z-direction positional error value of one of the principal surface of the substrate and the auxiliary plate portion relative to predetermined reference Z-positions with respect to said first, second and third detection systems.

6. An exposure apparatus according to Claim 5, wherein, if the predetermined reference Z-positions with respect to said first, second and third detection systems differ from each other, the differences between the reference Z-positions are detected by a calibration.

7. An exposure apparatus according to Claim 4, wherein, if the scanning direction of the substrate is a Y-direction and if a direction perpendicular to each of the Y-direction and the Z-direction is an X-direction, said first detection system includes a first focus detector of a multi-point type having a plurality of detection areas in a row along the X-direction on the substrate over a range of a size of the imaging field of said imaging system in the X-direction.

8. An exposure apparatus according to Claim 7, wherein said second detection system includes a plurality of second focus detectors having detection areas on opposite sides of the row of the plurality of

detection areas of said multi-point focus detector in the X-direction, each of said second focus detectors separately detecting the Z-direction position of the principal surface of one of the substrate and the auxiliary plate portion at each of the detection areas.

9. An exposure apparatus according to Claim 8, wherein said third detection system includes a plurality of third focus detectors on the opposite sides of the imaging field of said imaging system in the X-direction, each of said third focus detectors separately detecting the Z-direction position of the principal surface of one of the substrate and the auxiliary plate portion at each of the detection areas.

10. A projection exposure apparatus comprising:

(a) an imaging system for projecting an image of a mask pattern onto a substrate at a projection field;

(b) a movable stage mechanism for moving in intersecting X and Y directions to position the substrate with respect to the image of the projected mask pattern;

(c) an adjusting mechanism for adjusting a focus of the projected mask pattern image on the substrate;

d) a first detection system having a detection area at a first position located outside the projection field of said imaging system and spaced apart from the projection field in the Y direction, said first detection system detecting the position of a principal surface of the substrate in a Z direction;

(e) a second detection system having a detection area at a second position located outside the projection field of said imaging

system and spaced apart from said first position in the X direction, said second detection system detecting the position of the principal surface of the substrate in the Z direction;

(f) a third detection system having a detection area at a third position located outside the projection field of said imaging system, spaced apart from the projection field in the X direction and also spaced apart from said second position in the Y direction, said third detection system detecting the position of the principal surface of the substrate in the Z direction;

(g) a calculator coupled to said first and second detection systems, and calculating a deviation between the first Z-position detected by said first detection system and a target Z-position and for storing the second Z-position detected by said second detection system at the time of detection made by said first detection system; and

(h) a controller coupled to said adjusting mechanism ~~system~~ and said calculator and said third detection system, and controlling said adjusting mechanism on the basis of the calculated deviation, the stored second Z-position and the third Z-position detected by said third detection system when the area on the substrate corresponding to the detection area of said first detection system is positioned in the projection field of said imaging system by said movable stage mechanism.

11. An exposure apparatus according to Claim 10, wherein said first detection system includes a plurality of first focus detectors having a plurality of detection areas in a row along the X direction in a

range according to a size of the projection field of said imaging system in the X direction, each of said first focus detectors separately detecting the Z-position of the principal surface of the substrate at each of the detection areas.

12. An exposure apparatus according to Claim 11, wherein said second detection system includes two second focus detectors having two detection areas placed on opposite sides of the row of the plurality of detection areas of said first detection system, each of said second focus detectors separately detecting the Z-position of the principal surface of the substrate at each of the two detection areas.

13. An exposure apparatus according to Claim 12, wherein said third detection system includes two third focus detectors placed on opposite sides of the projection field of said imaging system in the X direction, each of said third focus detectors separately detecting the Z-position of the principal surface of the substrate at each of the two detection areas.

14. An exposure apparatus according to Claim 13, wherein said movable stage mechanism includes a mount portion for attracting a reverse surface of the substrate and an auxiliary plate portion which surrounds the substrate at a height substantially equal to the principal surface of the substrate when the substrate is supported on said mount portion, a surface of said auxiliary plate being detected by one of said two second focus detectors and one of said two third focus detectors.

15. A scanning exposure method in which a pattern

of a mask is transferred onto a sensitive substrate by projecting a part of the mask pattern on the sensitive substrate through a projection system and by moving the mask and the sensitive substrate relative to a projection field of the projection system, the method comprising the steps of:

(a) mounting the sensitive substrate on a holder having an auxiliary plate portion surrounding the sensitive substrate at a height substantially equal to a height of a principal surface of the sensitive substrate;

(b) reading a focus error of an exposure area of the sensitive substrate on which area a part of the mask pattern is to be projected, the focus error of the exposure area being read before the exposure area reaches the projection field of the projection system during scanning movement of the holder and the sensitive substrate;

(c) detecting a focus error of the principal surface of a part of one of the sensitive substrate and the auxiliary plate portion by an exposure position focus detection system disposed apart from the projection field of the projection system in a direction perpendicular to the direction of said scanning movement when the exposure area on the sensitive substrate reaches the projection field; and

(d) adjusting the focus between the projection system and the sensitive substrate on the basis of the focus errors detected by said steps (b) and (c) so that the focus error of the exposure area on the sensitive substrate is corrected in the projection field of the projection system.

16. A method according to Claim 15, applied to a

projection aligner having a projection system having an effective working distance to the principal surface of the substrate of 20 mm or less.

17. A method according to Claim 15, applied to an immersion projection exposure apparatus in which a space containing a projection optical path between the sensitive substrate and a transparent optical element disposed at an image plane side of the projection optical system is liquid filled.

18. A method according to Claim 17, wherein the projection optical system has a working distance such that the thickness of the liquid between the sensitive substrate and the transparent optical element of said projection optical system is 2 mm or less.

19. A method according to Claim 15, applied to a scanning exposure apparatus having a catadioptric projection system having a refractive optical material and a reflecting optical material, and in which a transparent optical element is disposed at an image plane side.

20. A method according to Claim 19, wherein the transparent optical element disposed at the image plane side is a prism mirror having an emergent surface substantially parallel to the principal surface of the sensitive substrate.

21. A focusing apparatus provided in an apparatus having an objective optical system to control focusing between a surface of a workpiece and the objective optical system, said focusing apparatus comprising:

(a) a first detection system having a detection area at a first position located outside

a field of said objective optical system, said first detection system detecting a position of the surface of the workpiece in the focusing direction;

(b) a second detection system having a detection area at a second position located outside the field of said objective optical system and spaced apart from said first position, said second detection system detecting the position of the surface of the workpiece in the focusing direction;

(c) a third detection system having a detection area at a third position located outside the field of said objective optical system and spaced apart from each of said first and second positions, said third detection system detecting the position of the surface of the workpiece in the focusing direction;

(d) a calculator coupled to said first and second detection systems, and calculating a deviation between the first focus position detected by said first detection system and a target focus position and for storing the second focus position detected by said second detection system at the time of detection made by said first detection system; and

(e) a controller coupled to said calculator and to said third detection system, and controlling focusing of the objective optical system on the surface of the workpiece on the basis of the calculated deviation, the stored second focus position and the third focus position detected by said third detection system when the area on the workpiece corresponding to the detection area of said first detection system is positioned in the field of said objective optical

system by relative movement of the workpiece and the objective optical system.

22. A method of controlling focusing of an objective optical system onto a surface of a workpiece when the workpiece and a field of the objective optical system are moved relative to each other in X and Y directions, said method comprising the steps of:

(a) mounting the workpiece on a holder having an auxiliary plate portion surrounding the workpiece at a height substantially equal to a height of the surface of the workpiece;

(b) reading a focus error of a predetermined local portion of the surface of the workpiece before the local portion of the workpiece reaches the field of the objective optical system during movement of said holder and the workpiece in a predetermined moving direction;

(c) detecting a focus error of the surface of a part of one of the workpiece and the auxiliary plate portion by a first focus detection system disposed apart from the field of the objective optical system in a direction perpendicular to the moving direction when the local portion of the workpiece reaches the field; and

(d) controlling the focusing between the objective optical system and the workpiece on the basis of the focus errors detected by said steps (b) and (c) so that the focus error of the local portion of the workpiece is corrected in the field of the objective optical system.

23. A method according to Claim 22, applied to at least one of a manufacturing instrument, a lithography exposure apparatus, a writing apparatus and an inspection apparatus having a small effective working

distance such that a detecting beam of an oblique incident light type focus detector cannot be obliquely led to the surface of the workpiece immediately below the objective optical system.

24. A projection exposure apparatus for projecting a mask pattern image onto a sensitive substrate through an optical imaging system and a liquid in a space between the substrate and the imaging system, said apparatus comprising:

an assembly holding a plurality of optical elements of said imaging system, wherein at least an end portion of said assembly is immersed in said liquid; and

a distal optical element mounted at the end portion of said assembly and having a distal surface which confronts the substrate and contacts said liquid;

wherein the distal surface of said distal optical element and a surface of the end portion of said assembly are substantially flush to each other, thereby suppressing disturbance of flowing of said liquid.

25. A method for fabricating a feature on a semiconductor wafer, employing a projection system, comprising the steps of:

(a) mounting the semiconductor wafer on a holder having a wall portion vertically provided at a peripheral portion to form a liquid layer on the wafer for achieving an immersed condition between a surface of the wafer and said projection system;

(b) scanning said holder along an image plane of said projection system to perform a scan-exposure by projecting a feature pattern image

onto the wafer through said projection system and said liquid layer; and

(c) correcting, during said scanning step, at least one of focus and tilt error between the surface of the wafer and the image plane of said projection system by using a focus detecting system which has a plurality of focus detection points disposed outside an image field of said projection system.

26. The method of Claim 25, wherein the projection system has a resolution less than 0.5 micrometers

27. A scanning exposure method to transfer a pattern of a mask onto a substrate through a imaging system, the method comprising the steps of:

providing a first detection system having a first detection area located outside a imaging field of the imaging system and spaced apart from the imaging field in a scanning direction, said first detection system detecting the position of a surface of the substrate in a optical axis direction of the imaging system;

providing a second detection system having a second detection area located outside a imaging field of the imaging system and spaced apart from the first detection area in a direction intersecting the scanning direction, said second detection system detecting the position of the surface of the substrate in the optical axis direction;

providing a third detection system having a third detection area located outside a imaging field of the imaging system and spaced apart from the imaging field in a direction intersecting the scanning direction and also spaced apart from the second detection area in the scanning direction, said third detection system detecting a deviation between the position of the surface of the substrate and a target position in the optical axis direction;

determining the target position of the third detection system based on the result of detection of the first and second detection system during an exposure of the substrate ; and

adjusting a positional relationship between the surface of the substrate and a imaging plane of the imaging system based on the result of detection of the first, second and third detection system during the exposure of the substrate.

3. Detailed Description of Invention

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to semiconductor fabrication and more particularly to a lithography exposure apparatus (aligner) for transferring a circuit pattern from a mask or a reticle onto a sensitive substrate.

The present invention also relates to a system for detecting a focal point on a workpiece (wafer, substrate or plate etc.) and for detecting a tilt of the workpiece, which is applicable to certain kinds of apparatus such as an apparatus for manufacturing a workpiece or imaging a desired pattern in a surface of a workpiece using a laser or electron beam and an apparatus for optically inspecting the state of a surface of a workpiece.

Description of the Related Art

Recently, dynamic random access memory semiconductor chips (DRAMs) having an integration density of 64 Mbits have been mass-produced by semiconductor fabrication techniques. Such chips are manufactured by exposing a semiconductor wafer to images of circuit patterns to form e.g. ten or more layers of circuit patterns in a superposition manner.

Presently, lithography apparatuses used for such chip fabrication are projection aligners in which a circuit pattern drawn in a chromium layer on a reticle (mask plate) is transferred onto a resist layer on a wafer surface through a 1/4 or 1/5 reduction optical imaging system by irradiating the reticle with i-line radiation (wavelength: 365 nm) of a mercury discharge lamp or pulse light having a wavelength of 248 nm from

a KrF excimer laser.

Projection exposure apparatuses (projection aligners) used for this purpose are generally grouped, according to the types of imaging optical system, into those using a step-and-repeat system, i.e., so-called steppers, and those using a step-and-scan system which has attracted attention in recent years.

In the step-and-repeat system, a process is repeated in which, each time a wafer is moved to a certain extent in a stepping manner, a pattern image on a reticle is projected on a part of the wafer by using a reduction projection lens system formed only of a refractive optical material (lens element) and having a circular image field or an unit magnification projection lens system formed of a refractive optical material (lens element), a prism mirror and a concave mirror and having a noncircular image field to expose a shot area on the wafer or plate to the pattern image.

In the step-and-scan system, a wafer is exposed to an image of a portion of a circuit pattern on a reticle (for example, in the form of a circular-arc slit) which is projected on the wafer through a projection optical system. Simultaneously, the reticle and the wafer are continuously moved at constant speeds at a speed ratio according to the projection magnification, thus exposing one shot area on the wafer to the image of the entire circuit pattern on the reticle in a scanning manner.

For example, as described on pp 256 to 269 of SPIE Vol. 922 Optical/Laser Microlithography (1988), the step-and-scan system is arranged so that, after one shot area on the wafer has been scanned and exposed, the wafer is moved one step for exposure of an adjacent shot area, and so that the effective image field of the projection optical system is limited to a circular-arc slit. Also, the projection optical system is

considered to be a combination of a plurality of refractive optical elements and a plurality of reflecting optical elements, such as one disclosed in U.S. Patent 4,747,678 (to Shafer).

U.S. Patent 5,194,839 (to Nishi) discloses an example of an aligner in which a step-and-scan system is realized by mounting a stepper reduction projection lens having a circular image field. This publication also discloses a method in which a pattern image projected at the time of scanning exposure is transferred onto a wafer by increasing the depth of focus (DOF) by a predetermined amount on the wafer.

In the field of lithography technology, it is now desirable to be able to fabricate semiconductor memory chips having an integration density and fineness of the 1 or 4 Gbit class by light exposure. Since light exposure techniques have a long technological history and are based on a large amount of accumulated know-how, it is convenient to continue use of light exposure techniques. It is also advantageous to use light exposure techniques considering drawbacks of alternative electron beam exposure or X-ray technologies.

It is believed that resolutions in terms of minimum line width (feature width) of about 0.18 μm and 0.13 μm are required with respect to 1 Gbit and 4 Gbit memory chips, respectively. To achieve resolution of such a line width, far ultraviolet rays having a wavelength of 200 nm or shorter, e.g., those produced by an ArF excimer laser, are used for illumination for irradiating the reticle pattern.

As optical vitreous materials having a suitable transmittance with respect to far ultraviolet rays (having a wave-length of 400 nm or shorter), quartz (S_iO_2), fluorite CaF_2, lithium fluoride (L_iF_2), magnesium fluoride (MgF_2) and so on are generally known. Quartz

and fluorite are optical vitreous materials indispensable for forming a projection optical system having high resolution in the range of far ultraviolet rays.

However, it is necessary to consider the fact that, if the numerical aperture (NA) of a projection optical system is increased to attain high resolution while the field size is increased, the diameter of lens elements made of quartz or fluorite becomes so large that it is difficult to manufacture such lens elements.

Also, if the numerical aperture (NA) of the projection optical system is increased, the depth of focus (DOF) ΔF is inevitably reduced. In general, the depth of focus ΔF is defined by wavelength, numerical aperture NA, a process coefficient Kf $(0 < Kf < 1)$ as shown below if the Rayleigh's theory of imaging formation is applied:

$\Delta F = Kf \bullet (\lambda / NA^2)$

Accordingly, the depth of focus ΔF in the atmosphere (air) is about 0.240 μm if the wavelength is 193 nm, that is, equal to that of ArF excimer laser light, the numerical aperture NA is set to about 0.75 and the process coefficient Kf is 0.7. In this case, the theoretical resolution (minimum line width) ΔR is expressed by the following equation using process coefficient Kr $(0 < Kr < 1)$:

$\Delta R = Kr \bullet (\lambda / NA)$

Accordingly, under the above-mentioned conditions, the resolution ΔR is about 0.154 μm if the process coefficient Kr is 0.6.

As described above, while it is necessary to increase the numerical aperture of the projection optical system in order to improve the resolution, it is important to notice that the depth of focus decreases abruptly if the numerical aperture is increased. If the depth of focus is small, there is a

need to improve the accuracy, reproducibility and stability with which an automatic focusing system for coincidence between the best imaging plane of the projection optical system and the resist layer surface on the wafer is controlled.

On the other hand, considering the projection optical system from the standpoint of design and manufacturing, a configuration is possible in which the numerical aperture is increased without increasing the field size. However, if the numerical aperture is set to a substantially larger value, the diameter of lens elements is so large that it is difficult to form and work the optical vitreous material (e.g. quartz and fluorite).

Then, as a means for improving the resolution without largely increasing the numerical aperture of the projection optical system, an immersion projection method may be used in which the space between the wafer and the projection optical system is filled with a liquid, see U.S. Patent 4,346,164 (to Tabarelli).

In this immersion projection method, the air space between the wafer and the optical element constituting the projection optical system on the projection end side (image plane side) is filled with a liquid having a refractive index close to the refractive index of the photoresist layer, to increase the effective numerical aperture of the projection optical system seen from the wafer side, i.e. improving the resolution. This immersion projection method is expected to attain good imaging performance by selecting the liquid used.

Projection aligners as presently known generally are provided with an automatic focusing (AF) system for precisely controlling the relative positions of the wafer and the projection optical system so that the wafer surface coincides with the optimum imaging plane (reticle conjugate plane) of the projection optical

system. This AF system includes a surface position detection sensor for detecting a change in the height position (Z-direction position) of the wafer surface in a non-contact manner, and a Z-adjustment mechanism for adjusting the spacing between the projection optical system and the wafer on the basis of the detected change.

Also in projection aligners presently used an optical type or air micrometer type sensor is used as the surface position detection sensor, and a holder (and a Z- stage) for supporting the wafer, provided as the Z-adjustment mechanism, is moved vertically to sub-micron accuracy.

If such an AF system is provided in an aligner to which the immersion projection method is applied, it is natural that an air micrometer type sensor cannot be used and an optical sensor is exclusively used since the wafer is held in a liquid. In such a case, an optical focus sensor, such as one disclosed in U.S. Patent 4,650,983 (to Suwa), for example, is constructed so that a measuring beam (an imaging beam of a slit image) is obliquely projected into the projection field on the wafer and so that the beam reflected by the wafer surface is received by a photoelectric detector through a light receiving slit. The change in the height position of the wafer surface, i.e., the amount of focus error, is detected from a change in the position of the reflected beam occurring at the light receiving slit.

If an oblique incident light type focus sensor such as the one disclosed in U.S. Patent 4,650,983 is directly mounted in a projection aligner in which the conventional projection optical system having a working distance of 10 to 20 mm is immersed in a liquid, a problem described below arises. In such a case, it is necessary to set in the liquid the optical system of

the projected beam emitted from a projecting objective lens of the focus sensor to reach the projection field of the projection optical system on the wafer and the optical system of the reflected beam reflected by the wafer to reach a light receiving objective lens.

Therefore, the beam of the focus sensor travels through a long distance in the liquid, so that unless the temperature distribution in the liquid is stabilized with high accuracy, the projected beam and the received beam fluctuate by a change in refractive index due to a temperature nonuniformity, resulting in deterioration in the accuracy of focus detection (detection of the height position of the wafer surface).

Moreover, to achieve a resolution of 0.15 λm or less by the immersion projection method, it is necessary to set the working distance of the projection optical system to a sufficiently small value, as mentioned above. Therefore, oblique projection itself of the projected beam of the oblique incident light type focus sensor from the space between the projection optical system and the wafer toward the projection area on the wafer becomes difficult to perform. For this reason, one important question arises as to how an automatic focusing system applicable to the immersion projection method is arranged.

On the other hand, aligners (exposure apparatus) having an unit magnification type (hereinafter described as "1X") projection optical systems are being used in the field of manufacturing liquid crystal display devices (flat panel displays) as well as in the field of manufacturing semiconductor devices. Recently, for this kind of aligner, a system has been proposed in which a plurality of 1X projection optical systems of a certain type are arranged and in which a mask and a photosensitive plate are moved integrally

with each other for scanning. It is desirable that, ideally, the working distance of the 1X projection optical systems used is extremely small. Each 1X projection optical system is of a single Dyson type such as that disclosed in U.S. Patent 4,391,494 (to Hershel) or a double Dyson type such as that disclosed in U.S. Patent 5,298,939 (to Swanson et al.).

In an aligner having such a Dyson type projection optical system, the working distance (spacing between the exit surface of a prism mirror and the image plane) can be sufficiently reduced to limit various aberrations or distortions of the projected image to such small values that there is practically no problem due to the aberrations or distortions. In this kind of aligner, therefore, a detection area on the photosensitive substrate of focus detection by the focus sensor (e.g., the irradiation position of the projected beam in the oblique incident light system or the air-exhaust position in the air micrometer system) is ordinarily set to a position deviating from the effective projection field region of the projection optical system, that is, set in an off-axis manner.

For this reason, it is impossible to actually detect whether the area of the substrate exposed to projected light from a circuit pattern is precisely adjusted in a best focus state or condition.

Also in apparatuses for writing a pattern on a substrate or to perform processing (or manufacturing) by using a spot of a laser beam or an electron beam, it is possible that the working distance between the substrate and the objective lens system (or an electronic lens system) for projecting the beam becomes so small that an AF sensor capable of detecting a focusing error of the processing position or the drawing position on the substrate surface in the field of the objective optical system cannot be mounted.

In such a case, the detection point of the AF sensor is only placed outside the field of the objective lens system to detect a focusing error, and it does not detect whether a focusing error occurs actually at the processing position or writing position in the field of the objective lens system.

The same can also be said with respect to an apparatus for optically inspecting a pattern drawn on a reticle or mask for photolithography or a fine pattern formed on a wafer. That is, this is because this kind of inspection apparatus is also provided with an objective lens system for inspection and because the end of the objective lens system faces a surface of an specimen (a plate) to be inspected while being spaced apart from same by a predetermined working distance.

Thus, if an objective lens system having a comparatively large magnifying power and high resolution is used, the working distance is so small that the same problem relating to the disposition of the AF sensor is encountered.

SUMMARY OF THE INVENTION

In view of the above-described problems of the related art, the present invention provides a projection aligner (exposure apparatus) and an exposure method which enable high-precision focusing control and high- precision tilt control even if a projection optical system to reduce the working distance in comparison with the conventional projection optical system is incorporated.

The invention is directed to a step-and-repeat aligner in which a surface of a sensitive substrate is exposed to a pattern image projected through an imaging system or a scanning exposure apparatus (scanning aligner) in which a mask (or a reticle) and a sensitive substrate are moved relative to an imaging system while

a pattern image is being projected, and to a system suitable for detecting a focal point and a tilt in these kinds of exposure apparatus (aligners).

In the present exposure apparatus and method, focusing control and tilt control are performed with respect to a shot area at a peripheral position on a sensitive substrate.

The present scanning exposure apparatus and scanning exposure method enable high-precision focusing control and high- precision tilt control with respect to an exposed area of a sensitive substrate, without setting a focus detection area in the projection field of a projection optical system.

The present focus sensor and focus detection method stably detect an error in focusing or tilting of a surface of a sensitive substrate immersed in a liquid in an immersion type projection aligner or scanning aligner designed to improve the depth of focus. The present focus sensor and focus detection method are suitable for a manufacturing (processing) apparatus, a drawing apparatus or an inspection apparatus having an objective optical system of a small working distance.

The present invention is applicable to a scanning exposure apparatus having an imaging system (a projection lens system) for projecting an image of a pattern of a mask (a reticle) on a substrate (a wafer) through an imaging field, a scanning mechanism (a reticle stage or wafer XY stage) for moving the mask and the substrate in a scanning direction relative to the imaging system, and a Z-drive system (a Z stage and Z-actuators) for driving the substrate and the imaging system relative to each other in a Z-direction to focus the projected image, or to a projection aligner (i.e, stepper) having an imaging system for projecting an image of a pattern of a mask on a substrate through a projection field, a movable stage mechanism which moves

in X and Y directions in order to position the substrate with respect to the image of the pattern to be projected, and a Z-drive mechanism for driving the substrate and the imaging system relative to each other in a Z-direction to focus the image to be projected.

The scanning mechanism or the movable stage mechanism of the exposure apparatus or aligner may be a mechanism for horizontally maintaining a mask or substrate. Alternatively, it may be a mechanism for maintaining a mask or substrate at a certain angle from a horizontal plane, for example, a vertical stage mechanism for moving a mask or substrate in a horizontal or vertical direction while maintaining the mask or substrate in a vertical attitude. In this case, a plane along which the mask or substrate is moved corresponds to X- and Y-directions, and Z-direction, perpendicular to each of X- and Y-directions, is also referred to (for example, in correspondence with the direction of the optical axis of a laterally-arranged projection optical system or the direction of principal rays).

According to the present invention, the aligner is provided with a first detection system having a detection area at a first position located outside the imaging field of the imaging system and spaced apart from same in the scanning direction (Y-direction), the first detection system detecting the position of an obverse (upper) surface of the substrate in the Z-direction, a second detection system having a detection area at a second position located outside the imaging field of the imaging system and spaced apart from the first position in a direction (X) (perpendicular to) the scanning direction (Y), the second detection system detecting the position of the obverse surface of the substrate in the Z-direction, a third detection system having a detection area at a third position located outside the

imaging field of the imaging system, spaced apart from the same in a direction (X) perpendicular to the scanning direction (Y) and also spaced apart from the second position in the scanning direction (Y), and the third detection system detecting the position of the obverse surface of the substrate in the Z-direction.

According to the present invention, the aligner is further provided with a calculator for calculating a deviation between the first Z-position detected by the first detection system and a target Z- position, and for temporarily storing the second Z-position detected by the second detection system at the time of detection made by the first detection system, and a controller for controlling the Z-drive system on the basis of the calculated deviation the stored second Z-position and the third Z-position detected by the third detection system when the area on the substrate corresponding to the detection area of the first detection system is positioned in the imaging field of the imaging system by a movement caused by the scanning mechanism or the movable stage mechanism.

The present invention is applicable to a scanning exposure method in which all of a pattern of a mask (a reticle) is transferred onto a sensitive substrate (a wafer) by projecting a part of the mask pattern on the sensitive substrate through a projection optical system and by simultaneously moving the mask and the sensitive substrate relative to a projection field of the projection optical system.

The present method includes the steps of mounting the sensitive substrate on a holder having an auxiliary plate portion formed so as to surround the sensitive substrate at a height substantially equal to the height of an obverse surface of the sensitive substrate, previously reading a focus error of an exposure area on the sensitive substrate on which area a part of the

pattern of the mask is to be projected, the focus error of the exposure area being read before the exposure area reaches the projection field of the projection optical system during scanning movement of the holder and the sensitive substrate, detecting a focus error of the obverse surface of a part of the sensitive substrate or the auxiliary plate portion by an exposure position focus detection system disposed apart from the projection field of the projection optical system in a direction (X) perpendicular to the direction (Y) of the scanning movement when the exposure area on the sensitive substrate reaches the projection field, adjusting the distance between the projection optical system and the sensitive substrate on the basis of the detected focus errors so that the focus error of the exposure area on the sensitive substrate is corrected in the projection field of the projection optical system.

A focus detection sensor or a focus detection method suitable for manufacturing (processing) apparatuses, imaging apparatuses and inspection apparatuses is achieved similarly by replacing the projecting optical system used for the above-described exposure apparatus (aligner) or the exposure method with an objective optical system for manufacturing, writing, imaging or inspection.

DETAILED DESCRIPTION

Fig. 1 shows the entire construction of a projection exposure apparatus in a first embodiment of the present invention, and which is a lens-scan type projection aligner in which a circuit pattern on a reticle is projected onto a semiconductor wafer through a reduction projection lens system having circular image fields telecentrically formed on the object side and the image side while the reticle and the wafer are being moved relative to the projection lens system to be scanned.

An illumination system shown in Fig. 1 includes an ArF excimer laser light source for emitting pulse light having a wavelength of 193 nm, a beam expander for shaping a cross section of the pulse light from the light source into a predetermined shape, an optical integrator such as a fly's- eye lens for forming a secondary light source image (a set of a plurality of point light sources) by receiving the shaped pulse light, a condenser lens system for condensing the pulse light from the secondary light source image into pulse illumination light having a uniform illuminance distribution, a reticle blind (illumination field stop) for shaping the pulse illumination light into a

rectangular shape elongated in a direction perpendicular to the scanning direction at the time of scanning exposure, and a relay optical system for imaging the rectangular opening of the reticle blind on a reticle R in cooperation with a mirror 11 and a condenser lens system 12 shown in Fig. 1.

The reticle R is supported on a reticle stage 14 by vacuum suction attraction. The reticle stage 14 can move at a constant speed in one dimension with a large stroke during scanning exposure. The reticle stage 14 is guided on a column structure 13 of an aligner body laterally as viewed in Fig. 1 to move for scanning. The reticle stage 14 is also guided so as to move in a direction perpendicular to the plane of the figure.

The coordinate position and the fine rotational deviation of the reticle stage 14 in an XY-plane are successively measured by a laser interferometer system (IFM) 17 which projects a laser beam onto a moving mirror (plane mirror or corner mirror) 16 attached to a portion of the reticle stage 14 and which receives the beam reflected by the mirror 16. A reticle stage controller 20 controls motors 15 (such as a linear motor or a voice coil) for driving the reticle stage 14 on the basis of the XY-coordinate position measured by the interferometer system 17, thereby controlling the scanning movement and the stepping movement of the reticle stage 14.

When a part of a circuit pattern area on the reticle R is irradiated with rectangular shaped pulse of light emitted from the condenser lens system 12, an imaging light beam from the pattern in the illuminated part is projected and imaged on a sensitive resist layer applied on the upper (principal) surface of a wafer W through a 1/4 reduction projection lens system PL. The optical axis AX of the projection lens system PL is placed so as to extend through center points of

the circular image fields and to be coaxial with the optical axes of the illumination system 10 and the condenser lens system 12.

The projection lens system PL includes a plurality of lens elements made e.g. of two different materials, such as quartz and fluorite having high transmittance with respect to ultra- violet rays having a wavelength of 193 nm. Fluorite is used mainly to form lens elements having a positive power. The air in the lens barrel in which the lens elements of the projection lens system PL are fixed is replaced with nitrogen gas so as to avoid absorption of the pulse illumination light having a wavelength of 193 nm by oxygen. Similar nitrogen gas replacement is performed with respect to the optical path from the interior of the illumination system 10 to the condenser optical system 12.

The wafer W is held on a wafer holder (chuck) WH which attracts the reverse (backside) surface of the wafer by vacuum suction. An annular auxiliary plate portion HRS is provided on a peripheral portion of the wafer holder WH so as to surround the circumference of the wafer W. The height of the surface of the auxiliary plate portion HRS is so as to be substantially flush with the upper surface of the wafer W attracted to the upper surface of the holder WH. This auxiliary plate portion HRS is used as an alternative focus detection surface if a detection point of a focus sensor is positioned outside the contour edge of the wafer W when a shot area at a peripheral position on the wafer W is scanned and exposed, as described below in detail.

Further, the auxiliary plate portion HRS can also serve as a flat reference plate (fiducial plate) for calibration of a system offset of the focus sensor in the same manner as disclosed in U.S. Patent 4,650,983 (to Suwa) mentioned above. Needless to say, a special

reference plate may be separately provided for calibration of the focus sensor.

The wafer holder WH is mounted on a ZL stage 30 which can translate in the Z-direction along the optical axis AX of the projection lens PL, and which can move in a direction perpendicular to the optical axis AX while tilting with respect to an XY-plane. The ZL stage 30 is mounted on an XY stage 34 through three Z-actuators 32A, 32B, and 32C. The XY stage 34 is movable two dimensionally in X- and Y-directions on a base. Each of the Z-actuators 32A, 32B, and 32C is e.g. a piezoelectric expansion element, a voice coil motor, or a combination of a DC motor and a lift cam mechanism.

If the three Z-actuators (or Z-drive motors) are each driven in the Z-direction to the same amount, the ZL stage 30 moves translationally in the Z-direction (focusing direction) while being maintained parallel to the XY stage 34. If the three Z-actuators are each driven in the Z-direction different amounts, an amount and a direction of the tilting of the ZL stage 30 is thereby adjusted.

The two-dimensional movement of the XY stage 34 is caused by several drive motors 36 which are e.g. a DC motor for rotating a feed screw or a linear motor or the like capable of producing a driving force in a non-contact manner. The drive motors 36 are controlled by a wafer stage controller 35 which is supplied with a measuring coordinate position from a laser interferometer (IFM) 33 for measuring changes in the position of a reflecting surface of a moving mirror 31 in the X- and Y-directions.

For example, the entire construction of the XY stage 34 using a linear motor as drive motor 36 may be as disclosed in Japanese Laid-Open Patent Application No.(Sho) 61-209831 (Tateishi Electronics Co.) laid open

on September 18, 1986.

With respect to this embodiment, it is assumed here that the working distance of the projection lens PL is so small that a projected beam of an oblique incident light type focus sensor cannot be led to the wafer surface through the space between the surface of the optical element of the projection lens system PL closest to the image plane and the upper surface of the wafer W. In this embodiment, therefore, three focus detection systems GDL, GDC, and GDR of an off-axis type (having a focus detection point out of the projection field of the projection lens PL) are disposed around a lower end portion of the barrel of the projection lens PL.

Of these focus detection systems, the detection systems GDL and GDR are set so as to have focus detection points positioned on the front and rear sides of the projection field with respect to the direction of scanning movement of the wafer W at the time of scanning exposure. When one shot area on the wafer W is scanned and exposed, one of the detection systems GDL ad GDR selected according to the direction of scanning movement (plus direction or minus direction) is operated so as to previously read the change in the surface height position in the shot area before exposure of the wafer to the rectangular projected image.

Accordingly, the focus detection systems GDL and GDR function, for example, as the same pre-read sensors as those of a focus detection system disclosed in U.S. Patent 5,448,332 (to Sakakibara et al.). In this embodiment, however, a focus adjustment (or tilt adjustment) sequence different from that of U.S. Patent 5,448,332 is used and a special focus detection system is therefore added to the focus detection systems GDL and GDR. This arrangement is described below in more

detail.

The focus detection system GDC shown in Fig. 1 has a detection point in a non-scanning direction perpendicular to the scanning direction of the projection field of the projection lens PL as seen on the surface of the wafer W (i.e., in an XY plane) in accordance with the off-axis method. However, the focus detection system GDC has another detection point on the back side of the projection lens PL as viewed in Fig. 1 in addition to its detection point on the front side.

The focus detection method in accordance with the present invention is characterized in that the off-axis focus detection system GDC and one of the pre-reading focus detection systems GDL and GDR are operated in cooperation with each other. Details of these focus-detection systems are described below.

Information on the height position of a portion of the wafer surface detected by each of the above-described focus detection systems GDL, GDR, and GDC (e.g., an error signal or the like representing the amount of deviation from the best focus position) is input to an automatic focusing (AF) control unit 38. The AF control unit 38 determines an optimal amount of driving of each of the Z-drive motors 32A, 32B, and 32C on the basis of the detection information supplied from the detection systems, and drives the Z-drive motors 32A, 32b, and 32C to perform focusing and tilt adjustment with respect to the area of the wafer W on which the projected image is to be actually imaged.

For this control, each of the focus detection systems GDL and GDR is a multi-point focus sensor having detection points at a plurality of positions (e.g., at least two positions) in the rectangular projection area on the wafer W formed by the projection lens PL, and the AF control unit 38 is capable of tilt

adjustment of the wafer W at least in the non-scanning direction (X-direction) as well as focusing.

The aligner shown in Fig. 1 is arranged to perform scanning exposure by moving the XY stage 34 at a constant speed in the Y-direction. The relation of the scanning movement and the stepping movement of the reticle R and the wafer W during scanning exposure will now be described with reference to Fig. 2.

Referring to Fig. 2, a fore-group lens system LGa and a rear-group lens system LGb represent the projection lens system PL shown in Fig. 1, and an exit pupil Ep exists between the fore-group lens system LGa and the rear-group lens system LGb. On the reticle R shown in Fig. 2, a circuit pattern area Pa having a diagonal length larger than the diameter of the circular image field on the object side of the projection lens PL is formed in a frame defined by a shield band SB.

To the image of the area Pa of the reticle R, a corresponding shot area SAa on the wafer W is exposed in a scanning manner by moving the reticle R at a constant speed Vr in the minus direction along the Y-axis while moving the wafer W at a constant speed Vw in the plus direction along the Y-axis, for example. At this time, the shape of pulse illumination light IA for illuminating the reticle R is set in the form of a parallel strip or a rectangle elongated in the X-direction in the area Pa of the reticle, as shown in Fig. 2. The ends of the shape of pulse illumination light IA opposite from each other in the X-direction are positioned on the shield band SB.

A partial pattern contained in the rectangular area in the area Pa of the reticle R irradiated with the pulse illumination light IA is imaged as an image SI at the corresponding position in the shot area SAa on the wafer W by the projection lens system PL (lens

systems LGa and LGb). When the relative scanning of the pattern area Pa on the reticle R and the shot area SAa on the wafer W is completed, the wafer W is moved one step, for example, to a certain distance in the Y-direction such that the scanning start position is set with respect to a shot area SAb adjacent to the short area SAa. During this stepping movement, the illumination with pulse illumination light IA is stopped.

Next, in order to expose the shot area SAb on the wafer W to the image of the pattern in the area Pa of the reticle R in a scanning manner, the reticle R is moved at the constant speed Vr in the plus direction of the Y-axis relative to pulse illumination light IA and the wafer W is simultaneously moved at the constant speed Vw in the minus direction of the Y-axis relative to the projected image SI. The speed ratio Vw/Vr is set to the reduction ratio 1/4 of the projection lens system PL. In accordance with the above-described schedule, a plurality of shot areas on the wafer W are exposed to the image of the circuit pattern area Pa of the reticle R.

The projection aligner shown in Figs. 1 and 2 can be used as a step-and-repeat aligner in such a manner that, if the diagonal length of ~~the of~~ the circuit pattern area on the reticle R is smaller than the diameter of the circuit image field of the projection lens system PL, the shape and size of the opening of the reticle blind in the illumination system 10 are changed so that the shape of illumination light IA conforms to the circuit pattern area. In such a case, the reticle stage 14 and the XY stage 34 are maintained in a relatively-stationary state during exposure of each of shot areas on the wafer W.

However, if the wafer W moves slightly during exposure, the slight movement of the wafer W may be

measured by the laser interferometer system 33 and the reticle stage 14 may be slightly moved under control so that the corresponding small error in the position of the wafer W relative to the projection lens system PL is canceled by follow-up correction on the reticle R side. For example, systems for such reticle follow-up correction are disclosed in Japanese Laid-Open Patent Application Nos. (Hei)6-204115 and (Hei)7-220998. Techniques disclosed in these publications may be used according to one's need.

If the shape or size of the opening of the reticle blind is changed, a zoom lens system may be provided to enable the pulse light reaching the reticle blind from the light source to be concentrated within the range matching with the adjust- ed opening according to the change in the shape or size of the opening.

Since the area of the projected image SI is set in the form of a strip or a rectangle elongated in the X-direction as clearly seen in Fig. 2, tilt adjustment during scanning exposure may be effected only along the direction of rotation about the Y-axis, that is, the rolling direction with respect to the scanning exposure direction in this embodiment. Needles to say, if the width of the projected image SI area in the scanning direction is so large that there is a need to consider the influence of flatness of the wafer surface with respect to the scanning direction, tilt adjustment in the pitching direction is performed during scanning exposure. This operation will be described in more detail with respect to another embodiment of the invention.

The focus detection systems GDL, GDR, and GDC shown in Fig. 1 are disposed as illustrated in Fig. 3, for example. Fig. 3 is a perspective view showing the disposition of detection points of the focus detection systems on the plane on which the circular image field

CP of the projection lens PL on the image side is formed. Fig. 3 shows only the disposition of the focus detection systems GDL and GDC. The focus detection system GDR is omitted since it has the same configuration as the detection system GDL.

Referring to Fig. 3, the focus detection system GDC has two detectors GDC1 and GDC2 which are set so that detection points (detection areas) FC1 and FC2 are positioned on an extension line LLc of the axis of the strip-like of rectangular projected image SI extending in the circular field CP of the projection lens PL in a diametrical direction (X- direction). These detectors GDC1 and GDC2 detect the height position of the upper surface of the wafer W (or auxiliary plate portion HRS) or a positioning error amount in the Z-direction with respect to the best focus plane position.

On the other hand, the focus detection system GDL includes in the embodiment five detectors GDA1, GDA2, GDB1, GBD2, and GDB3 having respective detection points (detection areas) FA1, FA2, FB1, FB2, and FB3 positioned on a straight line LLa parallel to the extension line LLc. Each of these five detectors independently detects the height position of a point on the upper surface of the wafer W (or auxiliary plate portion HRS) or a positioning error amount in the Z-direction with respect to the best focus plane position.

The extension line LLc and the straight line LLa are set at a certain distance from each other in the scanning direction (Y-direction). Also, the detection point FA1 of the detector GDA1 and the detection point FC1 of the detector GDC1 are set at substantially the same coordinate positions in the X-direction while the detection point FA2 of the detector GDA2 and the detection point FC2 of the detector GDC2 are set at substantially the same coordinate positions in the X-

direction.

The detection points FB1, FB2, and FB3 of three detectors GDB1, GDB2, and GDB3 are disposed so as to cover the area of the strip-like or rectangular projected image SI in the X- direction. That is, the detection point FB2 is disposed at a X-coordinate position corresponding to the center (the point at which the optical axis AX passes) of the area of the projected image SI in the X-direction while the detection points FB1 and FB3 are disposed at X-coordinate positions corresponding to positions in the vicinity of the opposite ends of the projected image SI area in the X-direction. Therefore, the three detection points FB1, FB2, and FB3 are used for focus error pre-reading of the surface portion of the wafer W corresponding to the projected image SI area.

The focus detection system GDR, not shown in Fig. 3, also has three pre-reading detectors GDE1, GDE2, GDE3 and other two detectors FDD1 and GDD2 disposed opposite sides of these pre-reading detectors in the X-direction. For ease of explanation, with respect to this embodiment, it is assumed that the planes recognized as best focus positions by the twelve detectors GDA1, GDA2; GDB1, GDB2, GDB3; GDC1, GDC2; GDD1, GDD2; GDE1, GDE2, GDE3 are adjusted to one XY-plane. That is, no system offset is provided between the twelve detectors and it is assumed that the surface height positions of the wafer W detected at the twelve detection points FA1, FA2; FB1, FB2, FB3; FC1, FC2; FD1, FD2; FE1, FE2, FE3 as positions at which the detected focus error becomes zero coincide closely with each other.

For the above-described twelve focus detectors, optical sensors, air micrometer type sensors, electrostatic capacity type gap sensors or the like can be used if the end of the projection lens PL is not

immersed in a liquid. However, if an immersion projection system is formed, it is, of course, impossible to use air micrometer type sensors.

Fig. 4 is a block diagram of an example of the AF control unit 38 for processing detection signals (error signals) from the focus detection systems GDL, GDR, and GDC shown in Figs. 1 and 3. As shown in Fig. 4, one of the group of detection signals from the five detectors GDA1, GDA2, GDB1, GDB2, and GDB3 of the pre-reading focus detection systems GDL and the group of detection signals from the five detectors GDD1, GDD2, GDE1, GDE2, and GDE3 of the focus detection systems GDR are selected by a changeover circuit 50 to be supplied to subsequent processing circuits.

The changeover circuit 50 selects the signals from one of the focus detection systems GDL and GDR in response to a changeover signal SS1 (representing a direction discrimination result) supplied from a position monitor circuit 52 which discriminates one scanning movement direction of the wafer stage 34 from the other on the basis of stage control information from the wafer stage controller 35, and which monitors changes in the moved position of the wafer W from the pre- read position to the exposure position. In the state shown in Fig. 4, the changeover circuit 50 is selecting the five detection signals from the focus detection system GDL.

The detection signals from the pre-reading detectors GDB1, GDB2, and GDB3 with respect to the exposure area (projected image SI) are supplied to a first calculator 54 for calculating a focus error amount and a tilt error amount. The calculator 54 supplies a second calculation and memory circuit 56 with error data DT1 and DT2 on focus error amount ΔZf and tilt error amount ΔTx (fine inclination about the Y- axis) of the surface area of the wafer W previously

read at the three detection points FB1, FB2, and FB3.

On the other hand, the detectors GDA1 and GDA2 supplies the second calculation and memory circuit 56 with information ZA1 and information ZA2 representing the surface height positions (or focus deviations) at the detection points FA1 and FA2 simultaneously with the detection of the wafer surface by the three detectors GDB1, GBD2, and GDB3.

The second calculation and memory circuit 56 calculates, on the basis of error data DT1, DT2, information ZA1, ZA2 and the relative positional relationship between the detectors, target values ΔZ1 and ΔZ2 of the height position of the wafer W which should be detected at the detection points FC1 and FC2 of the detectors GDC1 and GDC2 set at the projection exposure position with respect to the Y-direction (scanning direction). The second calculation and memory circuit 56 temporarily stores the calculated target values ΔZ1 and ΔZ2.

The meaning of the target values ΔZ1 and ΔZ2 is that, if information ZC1 and information ZC2 detected by the detectors GDC1 and GDC2 when the surface portions of the wafer W (or auxiliary plate portion HRS) previously read at the pre- reading detection points FA1 and FA2 reach the detection points FC1 and FC2 corresponding to the exposure position are equal to the target values ΔZ1 and ΔZ2, respectively, both the focus error amount ΔZf and tilt error amount ΔTx determined by pre-reading become zero at the exposure position.

Further, the second calculation and memory circuit 56 outputs the stored target values ΔZ1 and ΔZ2 to a third calculation and drive circuit 58 immediately before the pre-read area on the wafer with respect to the Y-direction arrives at the exposure position at which the projected image SI is exposed.

Accordingly, in synchronization with a signal SS2 output from the position monitor circuit 52, the second calculation and memory circuit 56 outputs signals representing target values ΔZ1 and ΔZ2 temporarily stored to the third calculation and drive circuit 58 after delaying the signals by an amount of time determined by the distance between the straight line LLa and the extension line LLc in the Y-direction and the speed of movement of the wafer W.

If signal SS2 is output each time the wafer W is moved to be scanned through a distance corresponding to the width of the projected image SI in the scanning direction, a certain number of sets of target values ΔZ1 and ΔZ2 (e.g., five sets) corresponding to a number obtained by dividing the distance between the straight line LLa and the extension line LLc in the Y-direction (e.g., about 40 mm) shown in Fig. 3 by the width of the projected image SI (e.g., about 8 mm) are temporarily stored in the second calculation and memory circuit 56. Accordingly, the second calculation and memory circuit 56 functions as a memory for storing target values ΔZ1 and ΔZ2 in a first in-first out (FIFO) manner.

The third calculation and drive circuit 58 reads, in response to a signal SS3 from the position monitor circuit 52, detection information ZC1 and ZC2 on the height position of the surface of the wafer W (or auxiliary plate portion HRS) detected by the detectors GDC1 and GDC2 immediately before the area on the wafer W detected at the pre-read position reaches the exposure position (the position of the projected image SI).

Simultaneously, the third calculation and drive circuit 58 reads the data of target values ΔZ1 and ΔZ2 (corresponding to the exposure position) output from the second calculation and memory circuit 56,

determines, by calculation, drive amounts (amounts of position adjustment or amounts of speed adjustment) corresponding to the Z-drive motors 32A, 32B, and 32C shown in Fig. 1 on the basis of information ZC1 and ZC2 and target values ΔZ1 and ΔZ2, and outputs determined drive amount data to the Z-drive motors 32A, 32B, and 32C.

It is to be understood that most of the element of Fig. 4 may be embodied in a programmed microcontroller or microprocessor, executing a suitable program which could be written by one of ordinary skill in the art in light of Fig. 4.

Fig. 5 is a plan view explaining the function of the auxiliary plate portion HRS formed at the peripheral portion of the wafer holder WH as shown in Fig. 1. In this embodiment, since all the detection points of the focus detection systems are positioned outside the projection field CP of the projection lens PL as described above, there is a possibility of some of the focus detection points being located outside the perimeter of wafer W at the time of scanning exposure of some of a plurality of shot areas SAn on the wafer arranged at the peripheral portion of the wafer W.

For example, as shown in Fig. 5, when a peripheral shot area SA1 of the wafer W positioned on the holder WH by using a prealignment notch NT is scanned and exposed, the end focus detection point FA1 (or FD1) of the pre-reading focus detection system GDL (or GDR) and the detection point FC1 of the exposure position focus detection system GDC are located outside the wafer W. In this state, it is difficult to normally perform focusing and tilt adjustment.

A main function of the auxiliary plate portion HRS is enabling normal focusing and tiling in such a situation. As shown in Fig. 5, the detection point FA1 (or FD1) and the detection point FC1 located outside

the of the wafer W are set so as to be positioned on the surface of the auxiliary plate portion HRS. Accordingly, it is desirable that the height of the surface of the auxiliary plate portion HRS is substantially equal to that of the surface of the wafer W.

More specifically, the surface of the wafer W and the surface of the auxiliary plate portion HRS are made flush with each other within the detection ranges which correspond to the detection points FA1 (FA2), FC1 (FC2), and FD1 (FD2) and in which the desired linearity of the focus detectors corresponding to the detection points are ensured. Further, since the surface of the auxiliary plate portion HRS is used as an alternative to the surface of the wafer W, its reflectivity is set on the same order or to the same value as the reflectivity of a standard (silicon) wafer. For example, a mirror-finished surface is preferred as the auxiliary plate portion HRS.

If the wafer W (on wafer holder WH) is moved to be scanned in the direction of the arrow shown in Fig. 5, the detection points FA1, FA2; FB1, FB2, FB3 of the focus detection system GDL are selected as pre-reading sensors with respect to the shot area SA1. In this event, if the distance between the extension line ~~Llc~~ LLc corresponding to the center of the projected image SI in the Y-direction and the straight line LLa on which the detection points of the focus detection system GDL are disposed is ~~Dla~~ DLa and if the distance between the extension line LLc and the straight line LLb on which the detection points of the other focus detection system GDR are disposed is DLb, DLa and Dlb are set so that DLa is approximately equal to DLb in this embodiment. From the speed Vw of the wafer W at the time of scanning exposure, the delay time Δt taken for the focus pre-read position on the wafer W to reach the

exposure position is $\Delta t = DLa/Vw$ (sec.). Accordingly, the time for temporary storage of target value data $\Delta Z1$ and $\Delta Z2$ in the second calculation and memory circuit 56 shown in Fig. 4 is substantially equal to the time lag Δt.

However, the distance DLa and the distance DLb may be selected so that DLa does not equal DLb according to a restriction relating the construction of the aligner. Needless to say, in such a case, the delay time of supply of the target values $\Delta Z1$ and $\Delta Z2$ are set to different lengths with respect to use of the pre-reading focus detection system GDL and use of the focus detection system GDR.

The focusing and tilting operations of the first embodiment arranged as described above is now described with reference to Figs. 6A through 6D. Fig. 6A schematically shows a state of the upper surfaces of the wafer W and the auxiliary plate portion HRS detected by the pre-reading focus detection system GDL at an instant during scanning exposure of the peripheral shot area SA1 of the wafer W as shown in Fig. 5.

In Figs. 6A through 6D, a horizontal line BFP represents the optimum focus plane of the projection lens PL. The detector GDB1 that detects the position of the wafer surface in the Z-direction at the focus detection point FB1 in the shot area SA1 outputs a detection signal representing $\Delta ZB1$ as a Z- position error (amount of defocusing) of the wafer surface with respect to the plane BFP. Similarly, the detectors GDB2 and GDB3 that detect errors of the position of the wafer surface in the Z-direction at the focus detection points FB2 and FB3 output detection signals representing errors $\Delta ZB2$ and $\Delta ZB3$. Each of these Z-position errors has a negative value if the wafer surface is lower than the best focus plane BFP, or has

a positive value if the wafer surface is higher than the best focus plane BFP.

The values of these errors ΔZB1, ΔZB2, and ΔZB3 are input to the first calculation and memory circuit 54 shown in Fig. 4. The first calculation and memory circuit 54 determines parameters of an equation representing an approximate plane APP (actually an approximate straight line) shown in Fig. 6B of the entirety of the pre-read portion in the shot area SA1 by the method of least squares or the like on the basis of these error values. The parameters thereby determined are focus error amount ΔZf and tilt error amount ΔTx of the approximate plane APP, as shown in Fig. 6B. The values of error amount ΔZf and amount ΔTx thus calculated are output as data DT1 and DT2 to the second calculation and memory circuit 56. In this embodiment, the focus error amount ΔZf is calculated as an error substantially at the middle point (corresponding to detection point FB2)of the shot area SA1 in the X-direction.

When the detectors GDB1, GDB2, and GDB3 detect Z-position errors as described above, the detectors GDA1 and GDA2 simultaneously detect Z-position errors ΔZA1 and ΔZA2 of the wafer surface or the surface of the auxiliary plate portion HRS with respect to the best focus plane at the detection points FA1 and FA2. These errors ΔZA1, ΔZA2 are temporarily stored in the second calculation and memory circuit 56.

Immediately after this detection and storage, assuming that the approximate plane APP such as that shown in Fig. 6B is corrected so as to coincide with the best focus plane BFP as shown in Fig. 6C, that is, the wafer holder WH is adjusted in the Z-direction and the tilting direction so that ΔZf = 0 and ΔTx = 0, the second calculation and memory circuit 56 calculates the Z-position target value ΔZ1 to be detected at the

detection point FA1 and the Z-position target value ΔZ2 to be detected at the detection point FA2 on the basis of data DT1 and DT2 (error amount ΔZf and ΔTx), Z-position errors ΔZA1, ΔZA2 actually measured at the detection points FA1 and FA2 and the distance DS between the middle point of the shot area and each of the detection points FA1 and FA2 in the X-direction. The calculated Z-position target values ΔZ1 and ΔZ2 are temporarily stored in the second calculation and memory circuit 56 until the pre-read area on the wafer W reaches the area of the projected image SI (exposure position).

When the pre-read area on the wafer W reaches the exposure position, the third calculation and drive circuit 58 shown in Fig. 4 reads the detection signals from the focus detectors GDC1 and GDC2 for detecting Z-position errors at the detection points FC1 and FC2. If, for example, the pre-read area on the wafer W is in a state such as shown in Fig. 6D immediately before it reaches the exposure position, the detector GDC1 outputs detection signal ZC1 representing a Z-position error at the detection point FC1 while the detector GDC2 outputs detection signal ZC2 representing a Z-position error at the detection point FC2.

Then the third calculation and drive circuit 58 calculates the drive amounts for the three Z-actuators 32A, 32B, and 32C necessary for tilting the wafer holder WH and/or translating the wafer holder WH in the Z-direction so that the values of detection signals ZC1 and ZC2 supplied from the detectors GDC1 and GDC2 become respectively equal to the Z-position target values ΔZ1 and ΔZ2 which are supplied from the second calculation and memory circuit 56 by being delayed. The third calculation and drive circuit 58 supplies the Z-actuators 32A, 32B, 32C with signals corresponding to the calculated drive amounts.

The shot area SA1 of the upper surface of wafer W is thereby precisely adjusted to coincide with the best focus plane BFP at the exposure position. As a result, the projected image SI of the pattern of the reticle R to be maintained in an optimal imaged state is exposed in the scanning mode of the shot area.

For this operation in the first embodiment, each detector in the pre-reading focus detection system GDL and each detector in the exposure position focus detection system GDC are set (calibrated) so as to output a detection signal indicating that there is no focus error when the surfaces of the wafer W or the auxiliary plate portion HRS coincide with the best focus plane BFP. However, it is difficult to strictly set the detectors in such a state. In particular, a detection offset between the detectors GDA1 and GDA2 (GDD1 and GDD2) in the pre-reading focus detection system GDL (GDR) and the exposure position focus detectors GDC1 and GDC2 steadily defocuses the pattern image formed on the wafer W for exposure.

Therefore, an offset value between the height position in the Z-direction at which the detector GDC1 detects the zero focus error and the height position in the Z-direction at which the detector GDA1 (GDD1) detects the zero focus error may be measured and stored by simultaneously performing focus detection by these detectors on the extremely high flatness surface of a reflective glass plate (or fiducial plate) provided on the wafer holder WH. This surface may be structure HRS or another structure separate from structure HRS. As a result, the correction by the stored offset value may be made when the Z-actuators 32A, 32B, and 32C are drive on the basis of the Z-position errors detected by the exposure position focus detectors GDC1 and GDC2.

The construction of a focus and tilt sensor in accordance with a second embodiment of the present

invention is next described with reference to Figs. ~~7A~~ 7 and ~~7B~~ 8. With respect to the second embodiment, a situation is supposed in which the projected image SI contained in the circular field of the projection lens PL has a comparatively large maximum width in the Y-direction (scanning direction) such that the influence of a tilt of the surface of wafer W in the Y-direction, i.e., pitching, is considerable.

As shown in Fig. ~~7A~~ 7, an exposure position focus detector GDC1 (not illustrated) is provided which has two detection points FC1a and FC1b disposed symmetrically about extension line LLc in the Y-direction above the projected image SI, and another exposure position focus detector GDC2 (not illustrated) is provided which has two detection points FC2a and FC2b disposed symmetrically about extension line LLc in the Y-direction below the projected image SI. Further, a pre-reading focus detector GDA1 having two detection points FA1a and FA1b disposed symmetrically about straight line LLa in the Y-direction and a pre-reading focus detector GDA2 (not illustrated) having two detection points FA2a and FA2b disposed symmetrically about straight line LLa in the Y- direction are provided. Similarly, a pre-reading focus detector GDD1 (not illustrated) having two detection points FD1a and FD1b disposed symmetrically about straight line LLb in the Y-direction and a pre-reading focus detector GDD2 having two detection points FD2a and FD2b disposed symmetrically about straight line LLb in the Y-direction are provided.

Pre-reading focus detectors GDBn (n = 1, 2, 3) (not illustrated) having pairs of detection points FB1a, FB1b; FB2a, FB2b; FB3a, FB3b, and pre-reading focus detectors GDEn (n = 1, 2, 3) (not illustrated) having pairs of detection points FE1a, FE1b; FE2a, FE2b; FE3a, FE3b are also provided. Each pair of

detection points are spaced apart from each other in the Y-direction.

The focus detection system shown in Fig. 7 ~~9A~~ reproduces adjustment amounts (i.e., target values $\Delta Z1$ and $\Delta Z2$) necessary for correcting the pre-read surface configuration (i.e., error amount ΔZf and ΔTx) of each shot area at the detection points of the off-axis detectors GDC1 and GDC2 in the same manner as the above-described first embodiment, thereby enabling focus adjustment in the Z-direction and tilt adjustment in the X-direction (rolling direction) of the exposure area.

In this embodiment, since the pre-reading focus detection system GDL (GDR) and the exposure position focus detection system GDC have pairs of detection points (FAna and FAnb; FBna ~~FEna~~ and FBnb; FCna and FCnb; FDna and FDnb; FEna and FEnb) spaced apart by a certain distance in the Y-direction, a tilt error amount ΔTy of the pre-read shot area in the pitching direction can be detected from the differences between Z-position errors at the detection points (... na, ... nb) forming pairs in the Y-direction, and adjustment amounts (i.e., target values $\Delta ZA1$, $\Delta ZA2$) necessary for correcting the surface configuration of the shot area including of the tilt error amount ΔTy, can be reproduced at the detection points (FCna and FCnb) of the off-axis detectors GDC1 and GDC2.

The detectors GDB1, GDB2, and GDB3 for detecting the focus positions at the detection positions FB1, FB2, and FB3 shown in Fig. 3 are disposed as systems independent of each other by being fixed to a lower portion of the projection lens PL. However, at least these three detectors GDB1, GDB2, and GDB3 may be arranged to detect the focus positions at the detection points FB1, FB2, and FB3 through a common objective lens system. The same can also be said with respect to

the group of three detectors GDE1, GDE2, and GDE3 for detecting the focus positions at the detection points FE1, FE2, and FE3 shown in Fig. 5.

Further, a common objective lens system may be used for the same purpose with respect to the group of six detectors for detecting the focus positions at the six detection points FBna and FBnb (n = 1, 2, 3) shown in Fig. 7 or the other group of six detectors for detecting the focus positions at the six detection points FEna and FEnb (n = 1, 2, 3). An arrangement of using a common objective lens system for detectors for detecting the focus positions at a plurality of detection points is therefore described briefly with reference to Fig. 8.

Fig. 8 is a schematic side view of the positional relationship between the projection lens and the detectors corresponding to the six detection points FBna and FBnb (n = 1, 2, 3) and the four detection points FA1a, FA1b, FA2a, and FA2b shown in Fig. 7 as seen in the Y-direction in Fig. 7. Accordingly, the scanning direction of the wafer W in Fig. 8 is a direction perpendicular to the plane of the figure and the five detection points FA1a, FBna (n = 1, 2, 3), and FA2a arranged in a row in the X direction at the leftmost position in Fig. 7 are representatively shown in Fig. 8. Another row of detection points FA1b, FBnb (n = 1, 2, 3), and FA2b are adjacent to the five detection points FA1a, FBna (n = 1, 2, 3), and FA2a (in a direction perpendicular to paper of Fig. 8). In this embodiment, the focus positions at these ten points are detected through the objective lens system.

As shown in Fig. 8, illumination light ILF from an illumination optical system 80A including a light source (e.g. a light emitting diode, a laser diode, a halogen lamp or the like) capable of emitting light in a wavelength range to which the resist layer on wafer W

is not sensitive is emitted through each of ten small slits formed in a multi-slit plate 81A. The ten small slits are disposed in correspondence with the ten detection points FBna, FBnb (n = 1, 2, 3), FA1a, FA1b, FA2a, and FA2b set on the wafer W. Light transmitted through the small slits is incident upon an objective lens 84A of a projection system via a lens system 82A and a reflecting mirror 83A and is deflected by a prism 85A by a desired angle to form a slit image at each detection point.

The illumination optical system 80A, the multi-slit plate 81A, the lens system 82A, the reflecting mirror 83A, the objective lens 84A and the prism 85A constitute a projection system of an oblique incident light type focus detection unit. The solid lines in the optical path from the multi-slit plate 81A to the wafer W shown in Fig. 8 ~~7B~~ represent principal rays of transmitted light from the small slits, and the broken lines in the optical path represent typical imaging rays slit ~~Slt~~ of the small slit imaging light imaged at the detection point FB2a (or FB2b).

The reflected light of the small slit imaging light reflected at each detection point on the wafer W is again imaged on a receiving slit plate 81B via a prism 85B, an objective lens 84B, a reflecting mirror 83B and a lens system 82B disposed generally symmetrically with respect to the projection system. Ten small receiving slits disposed in correspondence with the small slits in the projection multi- slit plate 81A are formed in the receiving slit plate 81B. Light transmitted through these receiving slits is received by a light receiving device 80B which is a plurality of photoelectric detection elements.

As the photoelectric detection elements of the light receiving device 80B, ten photoelectric detection elements are provided in correspondence with the

positions of the small slits of the receiving slit plate 81B to separately detect the focus positions at the detection points on the wafer. The light receiving device 80B, the receiving slit plate 81B, the lens system 82B, the reflecting mirror 83B, the objective lens 84B and the prism 85B constitute a light receiving system of the oblique incident light type focus detection unit. The solid lines in the optical path from the wafer W to the receiving slit plate 81B shown in Fig. ~~7B~~ 8 represent principal rays of the small slit images normally reflected by the wafer W, and the broken lines in the optical path represent typical imaging rays RSf from the detection point FB2a (or FB2b) to the receiving slit plate 81B.

The projection system and the receiving system shown in Fig. ~~7B~~ 8 are mounted on an integrally-formed metal member so that the positions of the components are accurately maintain- ed relative to each other. The metal member is rigidly fixed on the lens barrel of the projection lens PL. Another focus detection unit constructed in the same manner is disposed on the opposite side of the projection lens PL to separately detect the focus positions at the ten detection points FEna, FEnb (n = 1, 2, 3), FD1a, FD2a, FD1b, and FD2b shown in Fig. ~~7A~~ 7.

With respect to the pair of detection points FC1a and FC1b and the pair of detection points FC2a and FC2b shown in Fig. ~~7A~~ 7, oblique incident light type focus detection units each having a projection system and a receiving system arranged in the Y-direction of Fig. ~~7A~~ 7 (direction perpendicular to paper in Fig. ~~7B~~ 8) may be provided on the opposite sides of the projection lens PL in the X-direction. Also in the case where the focus position detection points are disposed as shown in Fig. 5, the oblique incident light type focus detection unit shown in Fig. ~~7B~~ 8 can also be applied in

the same manner.

A scanning aligner to which the present automatic focusing/tilt control system is applied is next described in accordance with a third embodiment of the present invention with reference to Fig. ~~8A~~ 9. This embodiment is applicable to a scanning aligner for a large substrate e.g. 300 mm diameter or greater having a 1X projection optical system formed of a tandem combination of a first-stage Dyson type (catadioptric) projection imaging system consisting of a pair of prism mirrors PM1 and PM2, a lens system PL1 and a concave mirror MR1 and a second-stage Dyson type projection imaging system consisting of a pair of prism mirrors PM3 and PM4, a lens system PL2 and a concave mirror MR2. Such an aligner is disclosed in U.S. Patent 5,298,939 (to Swanson et al.), for example.

In the aligner shown in Fig. ~~8A~~ 9, a mask M provided as an original plate and a plate P provided as a photosensitive substrate are integrally supported on a carriage 100, and a pattern on the mask M is transferred onto the plate P as a 1X (unit magnification) erect image by moving the carriage 100 to the left or right as viewed in Fig. ~~8A~~ 9 relative to the projection field of the 1X projection optical system and illumination light IL so as to scan the mask M and plate P.

In the case of the projection optical system for this type of aligner, it is desirable to minimize the spacing between the incidence plane of the prism mirror PM1 and the surface of the mask M and the spacing between the exit plane of the prism mirror PM4 and the upper surface of the plate P for reducing deteriorations in imaging performance (various aberrations and image distortion). In other words, if these spacings can be sufficiently reduced, the design of the lens systems PL1 and PL2 disposed on the optical

axes AX1 and AX2 becomes easier. Therefore, to achieve the desired imaging performance, it is necessary to reduce the spacing between the prism mirror PM1 and the mask M and the spacing between the prism mirrors PM4 and the plate P.

In view of this condition, for focusing and tilt adjustment of the pattern image projected by this projection, prereading focus detection systems GDL and GDR and an exposure position off-axis type focus detection system GDC such as those of the first embodiment (Fig. 3) or the second embodiment (Figs. ~~7A~~ 7, ~~7B~~ 8) are provided around the prism mirror PM4 as shown in Fig. ~~8A~~ 9 to precisely coincide the surface of the plate P and the best focus plane BFP at the exposure position immediately below the prism mirror PM4, by slightly moving the plate P in the Z-direction and the tilting direction.

Further, pre-reading focus detection systems GDL′ and GDR′ and an exposure position off-axis type focus detection system GDC′ may be disposed around the prism mirror PM1 on the mask M side so as to face the mask M, as shown in Fig. ~~8A~~ 9. These focus detection systems make it possible to detect a focus error and a tilt error of the area of the mask M irradiated with illumination light IL with respect to the prism mirror PM1 and to measure, in real time, a small deviation in the Z-direction (a focus shift of the image plane) and a tilt deviation (inclination of the image plane) of the best focus plane (i.e., a conjugate plane of reticle R) formed at a predetermined working distance from the prism mirror PM4.

Thus, in the aligner shown in Fig. ~~8A~~ 9, the image plane on which the pattern of the mask M is projected and imaged in an optimal condition by the projection optical system and the surface of the plate P can be adjusted to coincide with each other highly accurately

during scanning exposure.

The aligner shown in Fig. ~~8A~~ 9 may be constructed so that mask M and plate P stand vertically. Fig. ~~8B~~ 10 is a perspective view of an exemplary structure of a scanning aligner having a vertical carriage for vertically holding mask M and plate P and for integrally moving mask M and plate P with respect to a projection optical system for scanning. A scanning aligner having mask M and plate P held vertically in this manner is disclosed in Japanese Laid-Open Patent Application No. (Hei) 8-162401, for example.

Referring to Fig. ~~8B~~ 10, the entirety of the vertical type scanning aligner is constructed on a fixed base 120A which is placed on a floor with vibration isolators interposed between four corner portions of the fixed base 120A and the floor. Side frame portions 121A and 121B are provided on opposite side portions of the fixed base 120A so as to stand vertically (in the X-direction). A mask M is placed inside the side frame portion 121A while a plate P is placed inside the side frame portion 121B. In the side frame portion 121A, there- fore, an opening is formed in which an end portion of an illumination unit 122 having optical systems for illuminating mask M with exposure illumination light and for mask-plate alignment is inserted, as illustrated.

A guide base portion 123 is provided on the fixed base 120A so as to extend in the scanning direction (Y-direction) between the side frame portions 121A and 121B. Two straight guide rails 123A and 123B are formed on the guide base portion 123 so as to extend in the Y-direction parallel to each other. A vertical carriage 125 is supported by fluid bearings or magnetic floating bearings on the guide rails 123A and 123B reciprocatingly movably in the Y-direction. The vertical carriage 125 is driven in the Y-direction in a

non-contact manner by two parallel linear motors 124A and 124B having stators fixed on the guide base portion 123.

The vertical carriage 125 has a mask-side carriage portion 125A vertically formed inside the side frame portion 121A to hold mask M and a plate-side carriage portion 125B vertically formed inside the side frame portion 121B to hold plate P. A mask table 126A for slightly moving mask M in the X- or Y- direction in an XY-plane or in a rotational (θ) direction and for slightly moving mask M in the Z-direction while holding mask M is provided on the mask-side carriage portion 125A. On the other hand, a plate stage 126B for slightly moving plate P in the X- or Y-direction in an XY-plane or in a rotational (θ) direction and for slightly moving plate P in the Z-direction while holding plate P is provided on the plate-side carriage portion 125B.

A projection optical system PL such as one disclosed in Japanese Laid-Open Patent Application No. (Hei)8-162401 mentioned above is used in this embodiment. The projection optical system PL is constructed by arranging a plurality of sets (e.g., seven sets) of "1X" erect type double Dyson systems in the direction perpendicular to the X-direction. The plurality of sets of double Dyson systems are integrally combined and housed in a casing which is generally T-shaped as viewed in an XZ-plane. The projection optical system PL thus constructed is mounted by being suspended from upper end portions of the opposite side frame portions 121A and 121B so that predetermined working distances from mask M and plate P are maintained.

In the entire casing of the projecting optical system PL, mask M-side focus detection systems GDC', GDL', and GDR' on the mask M side and plate P-side

focus detection systems GDC, GDL, and GDR (on the plate P side) are provided so as to face mask M and plate P, respectively, as shown in Fig. ~~8A~~ 9. The detection points defined by the pre-reading focus detection systems GDL, GDL', GDR, and GDR' may be set in correspondence with the projection fields of the plurality of sets of double Dyson systems or may be arranged at predetermined intervals irrespective of the placement of the projection fields.

Fig. ~~8C~~ 11 is a perspective view of an example of a layout of detectors in mask M-side focus detection systems GDC', GDL', and GDR' provided in the casing of the projection optical system PL shown in Fig. ~~8B~~ 10. The effective projection fields DF1, DF2, DF3, DF4, DF5, ... of the plurality of sets of double Dyson systems are set as trapezoidal areas elongated in the X-direction perpendicular to the scanning direction. The trapezoidal projection fields DFn (n = 1, 2, 3 ...) are arranged in such a manner that the trapezoidal projection fields of each adjacent pair of double Dyson systems overlap each other by their oblique sides as seen in the X-direction.

While only the projection fields DFn on the mask M side are illustrated in Fig. ~~8C~~ 11, the projection fields on the plate P side are also arranged in the same manner. For example, the projection field DF2 shown in Fig. ~~8C~~ 11 is defined by a double Dyson system such as that shown in Fig. ~~8A~~ 9 including two concave mirrors MR2a and MR2b, and the projection field DF4 is defined by a double Dyson system including two concave mirrors MR4a and MR4b.

As shown in Fig. ~~8C~~ 11, detectors GDA1', GDB1', GDB2' ..., GDA2' (detectors GDA2' not being seen in Fig. ~~8C~~ 11) for the pre-reading focus detection system GDL' and detectors GDD1', GDE1', GDE2' ..., GDD2' (detectors GDD2' not being seen in Fig. ~~8C~~ 11) for the pre-reading focus detection system GDR' are disposed on the

opposite sides (on the front and rear sides with respect to the scanning direction) of the plurality of projection fields DFn. Also, exposure position focus detectors GDC1' and GDC2' (detector GDC2' not being seen in Fig. ~~8C~~ 11) are disposed at the opposite ends of the entire array of the plurality of projection fields DFn in the X-direction perpendicular to the scanning direction.

Each of the focus detectors described above is e.g. an air micrometer type electrostatic gap sensor. They may alternatively be oblique incident light type focus detectors. While only the focus detectors for detection on the mask M side are illustrated in Fig. ~~8C~~ 11, a plurality of detectors are also arranged in the same manner in the focus detection systems GDC, GDL, and GDR for detection of the plate P.

Adjustment portions KD1 and KD2 for adjusting various optical characteristics of the plurality of sets of double Dyson systems are provided on side portions of the casing of the projection optical system PL shown in Fig. ~~8B~~ 11. Therefore, a mechanism is provided to adjust the Z-direction position, i.e., to set a mechanical (optical) focus offset detected as a best focus plane by each focus detector, if the position of the best focus plane on the mask M side or plate P side is changed in the Z-direction in Fig. ~~8C~~ 11 by the optical characteristic adjustment.

This mechanism may be e.g. a mechanism which mechanically adjusts the position of a focus detector in the Z direction, or a mechanism which optically adjusts the position recognized as the best focus position by the focus detector in the Z direction, so that the optical path length is changed optically. Alternatively, the mask or plate are automatically adjusted for focus~~s~~ing in the Z direction according to detection signals which represent a focus error, and an

offset is added to its moved position in the Z direction.

A fourth embodiment in accordance with the present invention is next described with reference to Fig. ~~9~~12. This embodiment is applicable to an apparatus for performing projection exposure while immersing a projection end portion of a projection lens system PL in a liquid as described above. Fig. ~~9~~12 is a cross-sectional view of a portion of the apparatus from the end of the projection lens system PL and to a wafer holder WH.

A positive lens element LE1 having a flat lower surface Pe and a convex upper surface is fixed on the end of the projection lens system PL inside the lens barrel. The lower surface Pe of this lens element LE1 is finished so as to be flush with the end surface of the extreme end of the lens barrel, so that a flow of a liquid LQ is disturbed only to a minimal extent. To a lens barrel end portion of the projection lens system PL immersed in liquid LQ, detectors of pre-reading focus detection systems GDL and GDR and an exposure position focus detection system ~~GRD~~ GDC which are similar to those shown in Fig. 1 are attached so that their extreme end portions are immersed in liquid LQ.

A plurality of attraction surfaces 113 for attracting the reverse surface of wafer W by vacuum suction are formed in a central inner bottom portion of the wafer holder WH. More specifically, the attraction surfaces 113 have a plurality of circular-band-like land portions which have a height of about 1 mm and which are formed concentrically with each other with a predetermined pitch in the diametrical direction of the wafer W. Each of the grooves formed in central portions of the circular land portions communicates with a tubing 112 in the wafer holder WH. The piping 112 is connected to a vacuum source for vacuum suction.

In this embodiment, the spacing (substantial working distance) between the lower surface Pe of the lens element LE1 at the end of the projection lens system PL and the upper surface of the wafer W (or auxiliary plate portion HRS) in an optimum focus state, i.e., the thickness of liquid LQ in which a projection optical path is formed, is set to be 5 mm or less. Accordingly, the depth Hq of liquid LQ filling the wafer holder WH may be two to several times larger than this thickness (5mm or less), and the height of a wall portion LB vertically formed at the peripheral end of the wafer holder WH is about 10 to 25 mm. Thus in this embodiment, the thickness of liquid LQ in the imaging optical path corresponding to the working distance of the projection lens system PL is reduced, so that the total volume of liquid LQ filling the wafer holder WH is smaller and hence temperature control of the liquid [LQ] is easier.

In the region of liquid LQ in which the projection optical path is formed, a part of the illumination energy is absorbed when exposure light passes therethrough, so that an irradiation heat fluctuation can easily occur. If the depth Hq of liquid LQ is small, an increase in temperature due to such irradiation heat fluctuation occurs easily and an adverse effect of reducing the stability of temperature control may result. In such a case, a better effect is obtained by setting the depth Hq of liquid LQ to a value several times the substantial working distance, in order to disperse the influence of irradiation heat fluctuation in the large-volume liquid layer.

To provide focus detection systems GDL, GDR, and GDC as an optical type detection system in an immersion projection system such as that shown in Fig. ~~9~~ 12, one prevents the projected beam obliquely incident upon the surface of wafer W or auxiliary plate portion HRS and

the beam reflected by this surface from intersecting the interface between liquid LQ and air. An example of a focus/tilt detection system suitable for such an immersion projection type aligner is therefore described with reference to Fig. 13 ~~10~~.

Fig. 13 ~~10~~ shows the construction of a focus detection system GDL disposed in the vicinity of a projection lens system PL. Other detection systems GDR and GDC are constructed in the same manner as the detection system GDL. In Fig. 13 ~~10~~, the same components as those shown in Fig. 12 ~~9~~ are indicated by the same reference characters or numerals.

Referring to Fig. 13 ~~10~~, a prism mirror 200 formed of a glass block and having a lower portion immersed in liquid LQ is fixed in the vicinity of a peripheral portion of the projection lens system PL. The prism mirror 200 has reflecting surfaces 200a and 200b partially immersed in liquid LQ, and flat surfaces 200c and 200d through which the projected beam or reflected beam travels out of the glass of the prism mirror 200 into liquid LQ or out of liquid LQ into the glass. Also the prism mirror 200 has a flat upper surface.

A multi-slit plate 205 is illuminated through a condenser lens or a cylindrical lens 203 with light LK (having a non-actinic wavelength relative the resist on wafer W) from a light source 202 such as a light emitting diode (LED) or a laser diode (LD) for forming a projected beam for focus/tilt detection. A plurality of transmission slits corresponding to detection points (areas) FAn and FBn of the focus detection system GDL are formed in the slit plate 205. The light from each transmission slit is reflected by a beam splitter 207 and is incident upon an objective lens 209 to be converged as an imaging beam forming a slit image on the upper surface of wafer W.

The imaging beam emergent from the objective lens

209 enters the prism mirror 200 through the upper end surface of the same, is normally reflected by the reflecting surface 200a, and enters liquid LQ through the flat surface 200c to be obliquely incident upon the surface of wafer W to irradiate the same. The beam reflected by wafer W enters the prism mirror 200 through the opposite flat surface 200d, is normally reflected by the reflecting surface 200b and travels out of the prism mirror 200 through the upper end surface. This reflected light beam passes through an objective lens 211 and is reflected by a reflecting mirror 213 disposed at a pupil position of the objective lens 211.

The beam reflected by the mirror 213 travels reversely through the objective lens 211 and again travels via the reflecting surface 200 and the flat surface 200d of the prism mirror 200 to again irradiate wafer W. The light beam again reflected by wafer W travels via the flat surface 200c and the reflecting surface 200a of the prism mirror 200, passes the beam splitter 207 and is incident on a photoelectric detector 215. The photoelectric detector 215 is a plurality of light receiving elements corresponding to the slits of the slit plate 205. The photoelectric detector 215 separately outputs detection signals with respect to the detection points FAn and FBn, respectively.

Thus, the focus/tilt detection system shown in Fig. ~~10~~ 13, is arranged as a double-path system in which the projected beam reflected by wafer W is again reflected by wafer W, and can therefore have higher sensitivity for detection of an error in the wafer W surface position in the Z-direction in comparison with a single-path system.

In this embodiment, a glass block (prism mirror 200) is provided at the extreme end of the focus/tilt

detection system and is positioned so as to be partially immersed in liquid LQ, so that the projected beam and the reflected beam do not pass any interface between liquid LQ and air, thus providing a stable beam path. Moreover, the effective length of the path in liquid LQ through which the projected beam or reflected beam travels is reduced by virtue of the prism mirror 200, thereby avoiding any reduction in accuracy due to temperature variation of liquid LQ at the time of Z-position measurement.

Modified examples of the structure of the wafer holder WH shown in Figs. 1 and 5 are described with reference to Figs. 14 ~~11A~~ and 15 ~~11B~~. Fig. 14 ~~11A~~ is a cross-sectional view of a wafer holder WH to be mounted in a projection exposure apparatus for performing immersion exposure. In this example, fine Z- drive units 220 such as piezoelectric elements are provided which can slightly move an auxiliary plate HRS surrounding an attraction surface 113 on which wafer W is supported. The fine Z-drive units 220 move the auxiliary plate HRS in the Z-direction by a stroke of about several tens of micro-meters.

If the difference between the height of the surface of wafer W placed on the attraction surface 113 of the wafer holder WH and the height of surface of the auxiliary plate HRS in the Z-direction is larger than an allowable difference, this Z-drive unit 220 is used to correct the height of surface of the auxiliary plate HRS so that the difference is reduced to a value smaller than the allowable value.

As mentioned above with reference to Fig. 5, the surface of the auxiliary plate HRS functions as an alternative detection surface for the focus detection points FA1 (or FA2), FC1 (or FC2), and FD1 (or FD2) located outside wafer W when shot area SA1 at the peripheral portion of wafer W is exposed. However, when

inner shot area SA2 (see Fig. 5) of wafer W is exposed, these focus points are positioned on wafer W. Therefore, the focus detectors GDA1, GDA2, GDC1, GDC2, GDD1, and GDD2 having detection points each of which is not exclusively positioned on one of the surface of the auxiliary plate HRS and the surface of wafer W must accurately measure the Z-position on each of these surfaces. That is, it is necessary for the positions in the Z-direction of the surfaces of the auxiliary plate HRS and wafer W to be within the linear focus measuring range of the each focus detectors GDAn, GDCn and GDDn..

For example, if the linear focus measuring range of the focus detectors is ± 10 micrometers, the Z positional deviations of the surfaces of the auxiliary plate HRS and wafer W are limited within the range of several micrometers. However, the thickness of wafers varies in a tolerance determined by the SEMI standard, and it is difficult to limit the thicknesses of all usable wafers within the range of several micro-meters.

Therefore, when wafer W is attracted to the wafer holder WH shown in Fig. ~~11A~~ 14 before exposure, the difference between the Z-position of a suitable portion of the wafer W surface (e.g., a central portion of a peripheral shot area) and the Z-position of the surface of the auxiliary plate HRS is measured by using one of the focus detection systems (GDL, GRD, GDC) before exposure. If the difference exceeds the allowable range (e.g., several micro-meters), the height of the auxiliary plate HRS is adjusted so that the difference is within the allowable range by controlling the fine Z-drive units 220 shown in Fig. ~~11A~~ 14. Since the wafer holder WH shown in Fig. ~~11A~~ 14 is filled with liquid LQ, the fine Z-drive units 220 are "waterproofed" to prevent the liquid from entering the units.

The construction shown in Fig. ~~11B~~ 15 is next

described. Fig. ~~11B~~ 15 is a cross-sectional view of a modified example of the structure including a wafer holder WH and a ZL stage 30, which is suitable for exposure of a wafer in air. The components corresponding to those shown in Fig. ~~11A~~ 14 are indicated by the same reference characters or numerals. Referring to Fig. ~~11B~~ 15, the wafer holder WH is constructed as a chuck on which only an attraction surface 113 for supporting wafer W is formed, and which is fixed on a ZL stage 30.

An auxiliary plate HRS is mounted on the ZL stage 30 with fine Z-drive units 220 interposed therebetween. Each function point PV of three Z-actuators 32A, 32C, and 32B (32B not being seen in Fig. ~~11B~~ 15) for driving the ZL state 30 in the Z- direction and a tilting direction are set to points at a peripheral portion of the ZL stage 30 substantially at the same height as the wafer mount surface (attraction surface 113) of the wafer holder WH.

Also in the arrangement shown in Fig. ~~11B~~ 15, the height of the auxiliary plate HRS is adjusted to that of the upper surface of wafer W by using fine Z-drive units 220 in the same manner as shown in Fig. ~~11A~~ 14. This structure of the ZL stage 30 and the Z-actuators 32A, 32C, and 32B ~~32~~ shown in Fig. ~~11B~~ 15, in which ~~the height of~~ the height of the function points PV are set to the same level as the wafer surface, may also be applied to the aligner shown in Fig. 1. Also, the wafer holder WH of Fig. ~~11A~~ 14 may be mounted on the ZL stage 30 of Fig. ~~11B~~ 15 to form a focusing and tilting stage suitable for immersion projection exposure apparatus or its method.

The present invention has been described with respect to applications to exposure apparatus. However, the above-described embodiments can be modified in various ways with- out departing from the scope of the present invention. For example, the focus

detection systems GDL, GDR, and GDC may include electrostatic capacity type gap sensors or air micrometer type gap sensors in the case of an aligner for performing projection exposure in air. Also, the present invention is applicable e.g. to any of the step-and-repeat type, step-and-scan type and "1X" scanning type projection aligners using, as exposure light, g-line (463 nm) or i-line (365 nm) from a mercury discharge lamp or pulse light (248 nm) from KrF excimer laser.

According to the present invention, precise focusing and tilt control at the exposure position can be realized while the working distance of the projection optical system mounted in the projection aligner is set to an extremely small value, so that correction of various aberrations and distortion correction in optical design of the projection optical system become easier and the transparent optical element positioned near the image plane, in particular, can be reduced in size.

Each of the focusing/tilt control systems in accordance with the above-described embodiments of the present invention is applicable to a certain type of projection exposure apparatus. However, the present invention is also applicable to focus/tilt detection systems for beam processing (manufacturing) apparatuses, writing apparatuses, inspection apparatuses and the like and is not limited to semiconductor fabrication. These beam processing apparatuses, writing apparatuses and inspection apparatuses are provided with an optical or electrooptical objective system to which the present invention can be applied as a focus detection system for detecting a focus on a substrate, specimen or workpiece.

Fig. ~~12A~~ 16 shows the construction of a focus

detection system applied to an objective optical system of an apparatus for processing a workpiece with a laser or electron beam or for writing a pattern on a workpiece, and Fig. 17 ~~12B~~ shows a planar layout of detection points of the focus detection system shown in Fig. 16 ~~12A~~.

Referring to Fig. 16 ~~12A~~, a processing or writing beam LBW is deflected unidimentionally or two-dimensionally by a scanning mirror 300 and travels via a lens system 301, a fixed mirror 302 and a lens system 303 to be incident upon a beam splitter 304. The beam LBW is reflected by the beam splitter 304 to be incident upon a high-resolution objective system 305 having a small working distance. The beam LBW is condensed into a small spot having a predetermined shape (e.g., a variable rectangular shape) on a workpiece WP by the objective system 305.

The workpiece WP is attracted to and fixed on the same holder WH as that shown in Fig. 14 ~~11A~~ or 15 ~~11B~~. An auxiliary plate HRS is attached integrally to the holder WH around the workpiece WP. The holder WH is fixed on an unillustrated XYZ- stage to be moved two-dimensionally in a horizontal direction and in a direction perpendicular to paper as viewed in Fig. 16 ~~12A~~. The holder WH is also moved slightly in the vertical direction (Z-direction) for focusing.

The apparatus shown in Fig. 16 ~~12A~~ is also provided with an optical fiber 310 for emitting illumination light for observation, alignment or aiming, a beam splitter 311 and a lens system 312 for leading the illumination light to the above-mentioned beam splitter 304, and a light receiving device (e.g. or photomultiplier, image pickup tube, CCD or the like) 314 for photoelectrically detecting reflected light, scattered and diffracted light or the like from the workpiece WP obtained through the objective system 305.

Pre-reading focus detection systems GDL and GDR and a processing position focus detection system GDC are provided around the objective system 305. Fig. ~~122~~ 17 shows a field 305A of the objective system 305 and a planar layout of detection points of the focus detection systems disposed around the field 305A. For convenience, the center of the field 305A is set at the origin of an XY coordinate system. A rectangular area in the field 305A indicates the range through which the spot of the beam LBW scans by the deflection of the beam caused by the scanning mirror 300.

Focus detectors GDA1, GDBn, and GDA2 on the left-hand side of the field 305A of the objective system are disposed so that detection points FA1, FB1, FB2, FB3, and FA2 is set in a row parallel to the Y-axis. Also, focus detectors GDD1, GDEn, and GDD2 on the right-hand side of the field 305A are disposed so that detection points FD1, FE1, FE2, FE3, and FD2 is set in a row parallel to the Y-axis.

On the other hand, a focus detector GDC1 provided above the field 305A is set so that three detection points FD1a, FD1b, and FD1c are placed on a line passing the two detection point FA1 and FD1 and parallel to the X-axis while a focus detector GDC2 provided below the field 305A is set so that three detection points FD2a, FD2b, and FD2c are placed on a line passing the two detection point FA2 and FD2 and parallel to the X-axis. In this embodiment, a set of the focus detectors GDA1, GDBn and GDA2 and a set of the focus detectors GDD1, GDEn and GDD2 are selected as the focus pre-reading function while the workpiece WP moves in the X-direction. On the other hand, the focus pre-reading function is achieved by selecting a set of the focus detectors GDA1, GDC1 and GDD1 and a set of the focus detectors GDA2, GDC2 and GDD2 while the workpiece WP moves in the Y-direction. This embodiment

is arranged so that the detection points of the focus detectors GDBn, GDC1, GDC2, and GDEn can be changed for detecting a focus of the processing position. For example, when the workpiece WP is moved in the X direction from the left-hand side to the right-hand side of Fig. 16 ~~12~~, one of three pairs of detection points FD1a and FD2a, detection points FD1b and FD2b, and detection points FD1c and FD2c may be selected for focus detection of the processing position while the detection points FA1, FB1, FB2, FB3, and FA2 are being used for pre-reading.

This arrangement is intended to achieve an effect described below. That is, the position of the spot of the processing or drawing light beam LBW changes in the scanning range 305B. Therefore, when for example, the light spot is positioned at the leftmost end of the scanning range 305B as seen in Fig. 17 ~~12B~~, the two detection points FD1a and FD2a are selected for processing position focus detection. When the light spot is positioned at the rightmost end of the scanning range 305B, the two detection points FD1c and FD2c are selected for processing position focus detection.

In this manner, the reproducibility and accuracy of focus control or tilt control are improved. The holder WH ~~12A~~ shown in Fig. 16 ~~12A~~ is slightly moved in the focusing (Z) direction and in a tilting directions on the XY stage. As is a drive system and a control system for this movement, those shown in Fig. 4 can be used without being substantially modified.

As described above, the focus detection system shown in Fig. 16 ~~12A~~ and 17 ~~12B~~ is arranged to enable pre-reading detection of the focus in each of the directions of the two-dimensional movement of workpiece WP and to enable the focus detection point for the processing position to be selected according to the position of the beam spot in the field 305A. As a

result, even a peripheral portion of workpiece WP is precisely processed (imaged) in an accurately focused state or pattern imaging can be performed thereon in such a state.

An inspection apparatus to which the focus/tilt detection system of the present invention can be applied is described briefly with reference to Fig. 18 ~~13~~ which shows an example of an apparatus for optically inspecting defects in patterns drawn on a mask or reticle for photolithography or defects in circuit patterns of a semiconductor device or liquid crystal display device formed on a substrate.

In recent years, techniques for examining the quality of an inspected pattern formed on a specimen (substrate) and checking the presence or absence of extraneous materials or particles and damage by enlarging the inspected pattern through an objective optical system, by forming an enlarged image of the pattern by a CCD camera or the like and by analyzing an image signal obtained from such an image have been constructively introduced into this kind of inspection apparatus.

In such a case, it is important to improve the accuracy with which an accurately enlarged image of the inspected pattern is obtained. An objective system having high resolution and a large field size and capable of forming an image with minimized aberrations and distortion is therefore required. Such an objective system naturally has a small working distance and is ordinarily designed as a through the lens (TTL) type such that focus detection is made through the objective system. However, a TTL optical focus detection system entails a problem of limiting the detection sensitivity (the amount of change in detection signal with respect to an error in focusing a specimen) because of a restriction due to the numerical

aperture (NA) of the objective system.

If a TTL focus detection system is formed so as to use light having a wavelength different from that of illumination light for inspection, aberration correction must be taken into consideration with respect to the wavelength ranges of inspection illumination light and focus detection illumination light in the optical design of the objective system. In such a case, the lens cannot always be designed optimally with respect to inspection illumination light.

Then, as shown in Fig. 18 ~~13~~, a plurality of sets of focus detection systems GDC, GDL, and GDR are provided around an objective lens 330 for inspection in the same manner as those shown in Figs. 16 ~~12A~~ and 17 ~~13B~~. A specimen WP to be inspected is e.g. a mask having a pattern Pa formed on its lower surface. The specimen WP is supported at its peripheral end on a frame-like two-dimensionally-movable stage 331 having an opening. The objective lens 330 is mounted in an upward-facing state on a base member 332 for guiding movement of the stage 331. An enlarged image of a local area in pattern Pa is imaged on an imaging plane of an image pickup device 336 through a beam splitter 334 and a lens system 335 ~~35~~.

On the opposite side of the specimen WP, a condenser lens 338 of an illumination optical system is disposed coaxial with the axis AX of the objective lens 330. Illumination light from an optical fiber 340 travels through a condenser lens 341, an illumination field stop 342 and a lens system 343 to be incident upon the condenser lens 338, thereby irradiating the area on the specimen WP corresponding to the field of the objective 330 with a uniform illuminance.

In the above-described arrangement, the focus detection systems GDC, GDL and GDR are mounted on the base member 332 together with the objective ~~30~~ 330 so as to

upwardly face the pattern Pa. A plurality of focus detectors (a plurality of detection points) are provided in the focus detection systems GDL and GDR provided for pre-reading, while at least one pair of focus detectors is provided in the focus detection system GDC for detection at the inspection position.

Also in the focus detection system shown in Fig. 18, the specimen WP on the stage 331 may be moved vertically along the optical axis AX or tilted on the basis of focus position information detected by the focus detectors by using a control circuit such as that shown in Fig. 4. In the inspection apparatus shown in Fig. 18, however, only an effect of obtaining a high-quality enlarged image of the pattern Pa imaged by the image pickup device 336 may suffice. Therefore, a focus adjuster 352A or 352B for slightly moving the objective lens 330 or the lens system 335 along the optical axis AX may be provided instead of the means for vertically moving the specimen WP.

An inspection apparatus in which a mask pattern Pa provided as a specimen WP is positioned so as to face downward has been described by way of example with reference to Fig. 18. Needless to say, this embodiment can be directly applied to an inspection apparatus in which pattern Pa faces upward, while the objective lens faces downward. In the apparatus shown in Fig. 18, a transmitted image of pattern Pa is inspected by a coaxial transmission illumination system.

However, the illumination system may be changed so that coaxial reflection illumination light is introduced through the beam splitter 334 in the direction of the arrow 350 in Fig. 18. In such a case, the enlarged image received by the image pickup device 336 is formed by imaging reflected light from the pattern Pa.

Further, another method may be used in which a

spatial filter with a transmission portion having a desired shape is removably placed at the position of a Fourier transform plane formed in the optical path of the illumination optical system or in the imaging optical system to enable a bright field image or a dark field image of pattern Pa to be selectively imaged on the image pickup device 336.

This disclosure is illustrative and not limiting; further modifications will be apparent to one of ordinary skill in the art in light of this disclosure, and are intended to fall within the scope of the appended claims.

4 Brief Description of Drawings

Fig. 1 is a diagram showing a scanning projection exposure apparatus (aligner) in a first embodiment of the present invention;

Fig. 2 is a schematic perspective view explaining a scanning exposure sequence;

Fig. 3 is a schematic perspective view of the disposition of a focus detection system provided in the vicinity of an end of the projection lens system shown

in Fig. 1;

Fig. 4 is a circuit block diagram of a circuit arrangement in the AF control unit shown in Fig. 1;

Fig. 5 is a plan view of the positional relationship between a projection field and detection areas of focus sensors on the wafer in the apparatus shown in Fig. 1;

Figs. 6A, 6B, 6C, and 6D are diagrams of the focusing and tilting operation of the apparatus shown in Fig. 1;

Fig. ~~7A~~ 7 is a plan view of a layout of detection areas of a focus/tilt detection system in a second embodiment of the present invention;

Fig. ~~7B~~ 8 is a side view of a layout of a modified example of the focus/tilt detection system shown in Fig. ~~7A~~ 7;

Fig. ~~8A~~ 9 is a schematic diagram in a third embodiment of the present invention in which the invention is applied to a scanning exposure apparatus (scanning aligner);

Fig. ~~8B~~ 10 is a perspective view of a vertical carriage applied to the scanning aligner shown in Fig. ~~8A~~ 9;

Fig. ~~8C~~ 11 is a perspective view of a projection optical system and a focus detection system provided in the projection aligner shown in Fig. ~~8A~~ 9;

Fig. ~~9~~ 12 is a cross-sectional view in a fourth embodiment of the present invention in the construction of which the invention is applied to an immersion projection exposure apparatus;

Fig. ~~10~~ 13 is a diagram showing an example of an optical path layout of a focus/tilt detection system suitable for the immersion projection exposure apparatus;

Figs. ~~11A~~ 14 and ~~11B~~ 15 are cross-sectional views of modified examples of the wafer holder;

Fig. 16 ~~12A~~ is a diagram showing an example of a manufacturing or imaging or writing apparatus to which the focus detection sensor of the present invention is applied;

Fig. 17 ~~12B~~ is a plan view showing an exemplary layout of the focus detection system applied to the apparatus shown in Fig. 16 ~~12A~~; and

Fig. 18 ~~13~~ is a diagram schematically showing the construction of an exemplary inspection apparatus to which the focus/tilt detection system of the present invention is applied.

Fig. 1

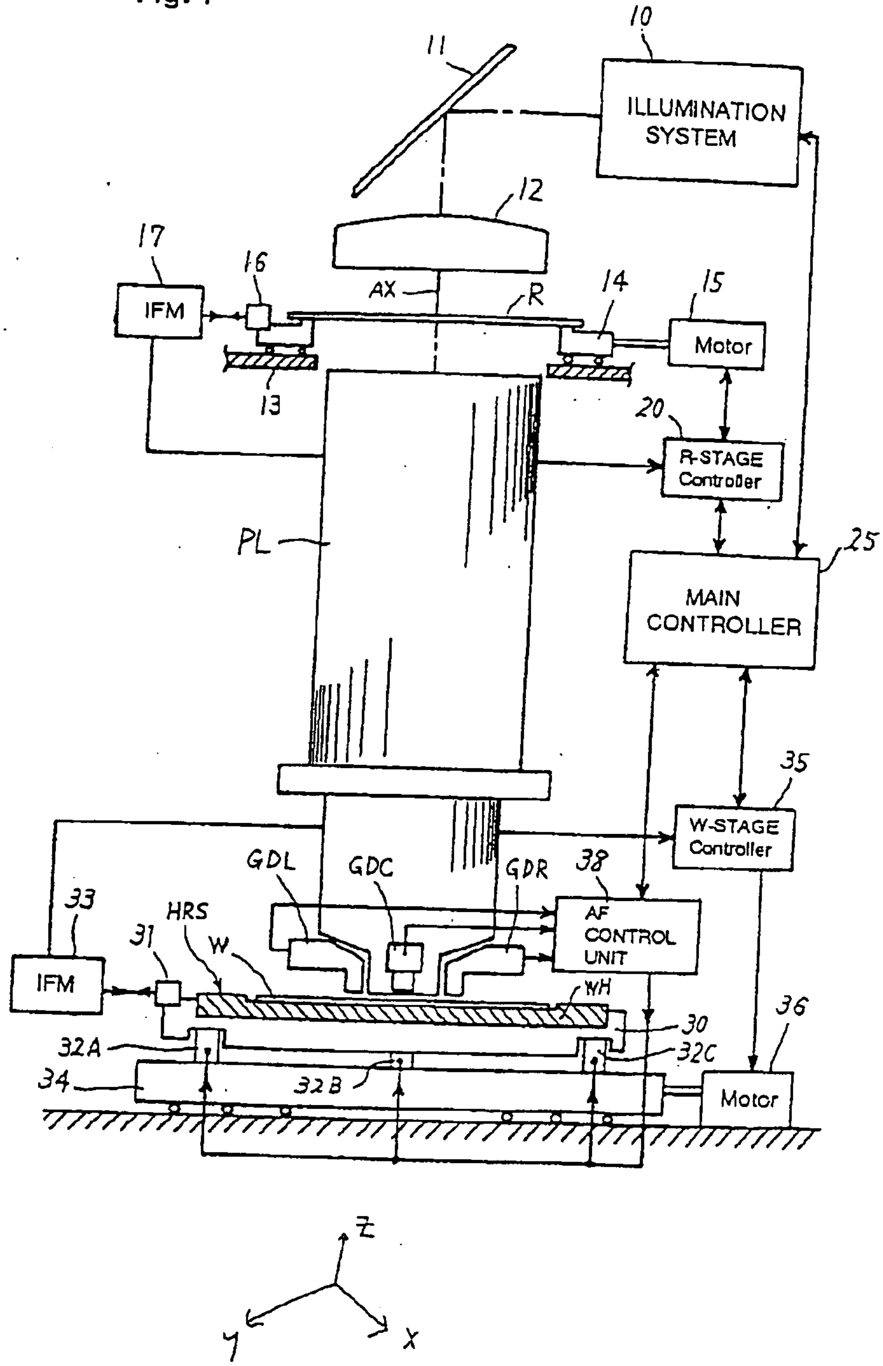

10
11
ILLUMINATION SYSTEM
12
17
16
AX
R
14
15
IFM
Motor
13
20
R-STAGE Controller
PL
25
MAIN CONTROLLER
35
W-STAGE Controller
GDL
GDC
GDR
38
33
HRS
31
W
AF CONTROL UNIT
IFM
WH
30
32A
32C
36
34
32B
Motor
Z
Y
X

Fig. 2

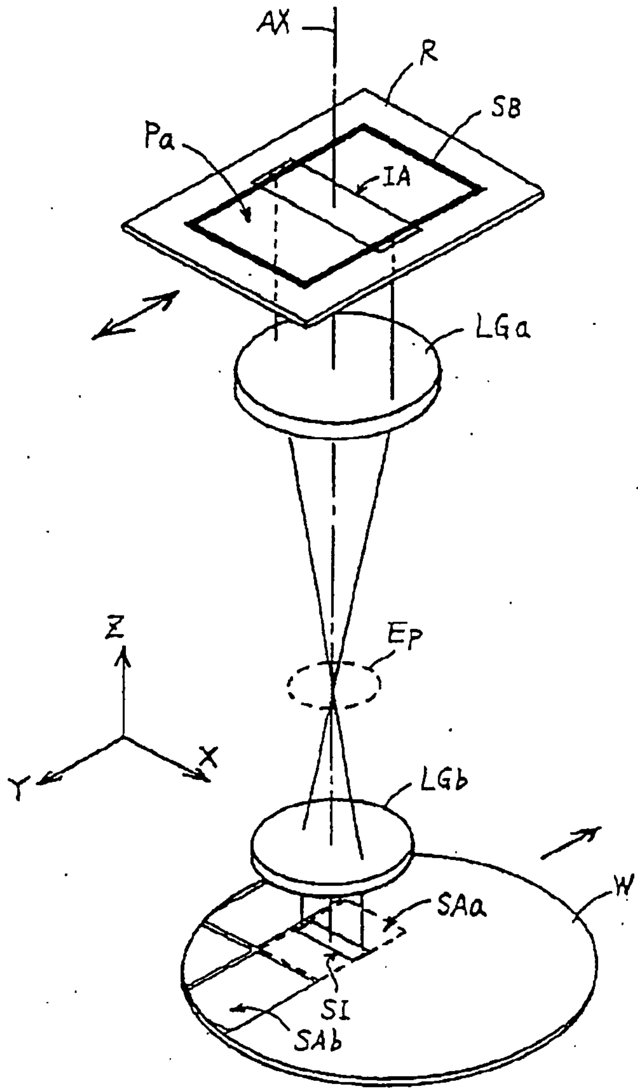
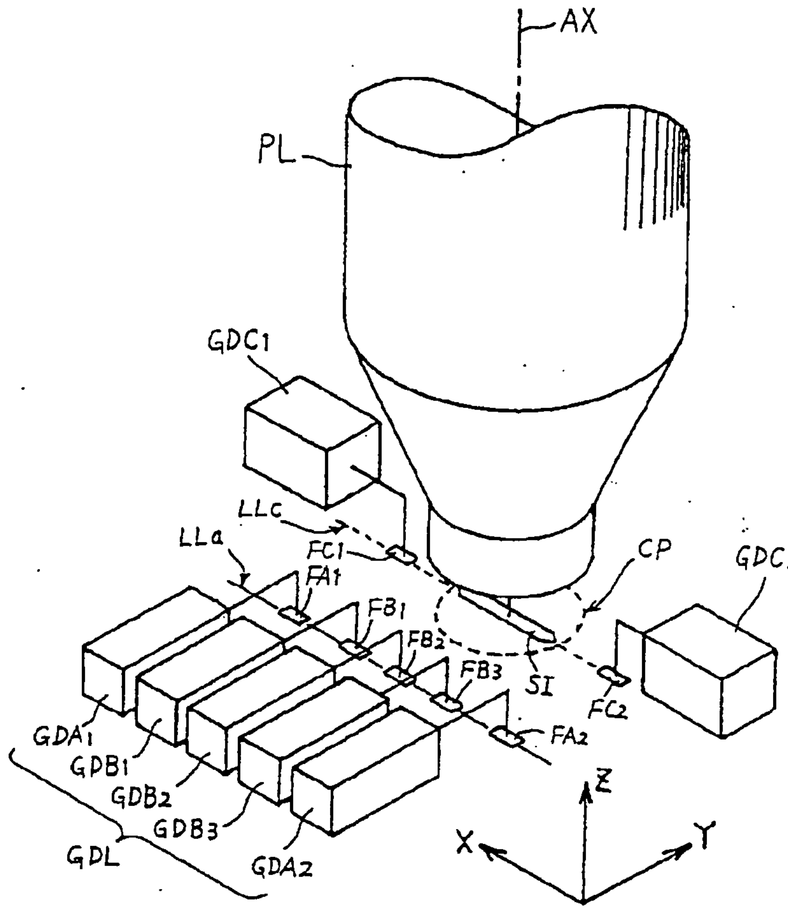


Fig. 3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GDC1
LLc
LLa
FC1
FA1
FB1
FB2
FB3
FA2
CP
GDC2
SI
FC2
GDA1
GDB1
GDB2
GDB3
GDA2
GDL
Z
X
Y

Fig. 4

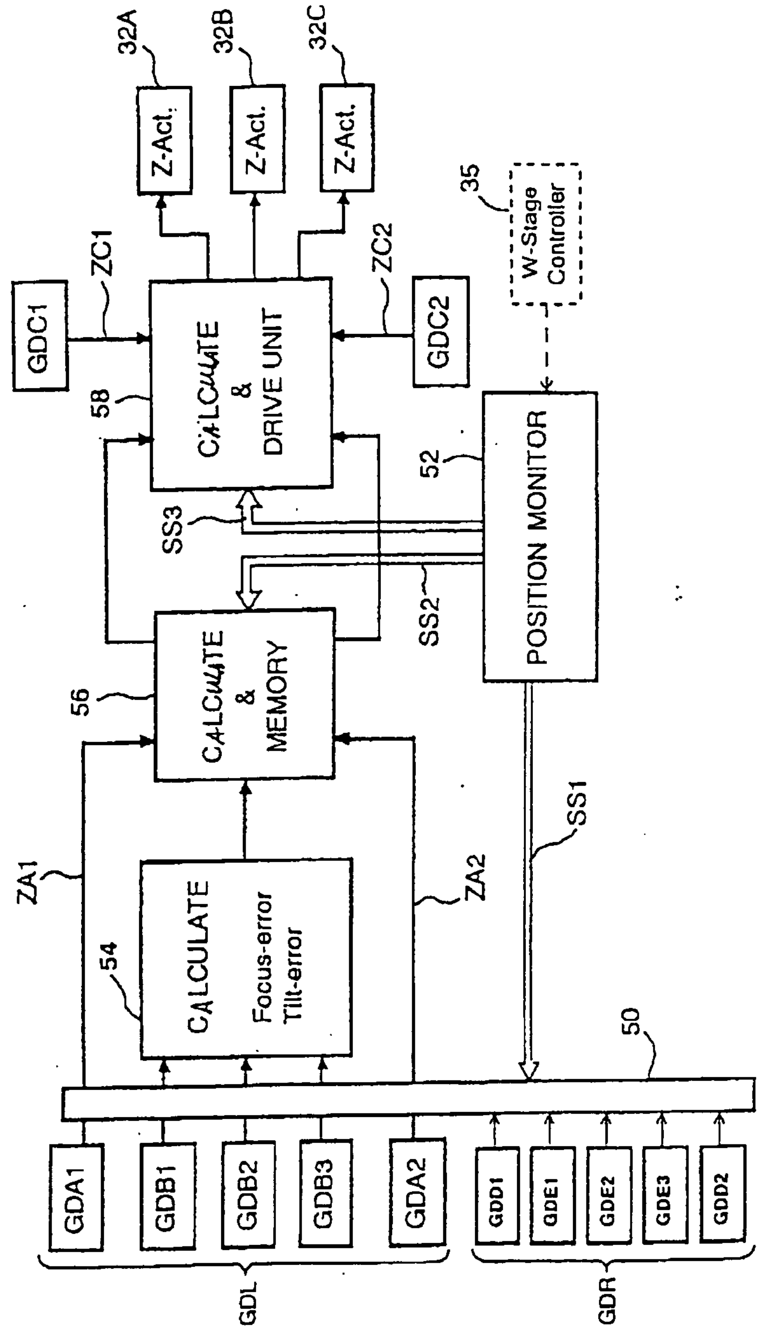
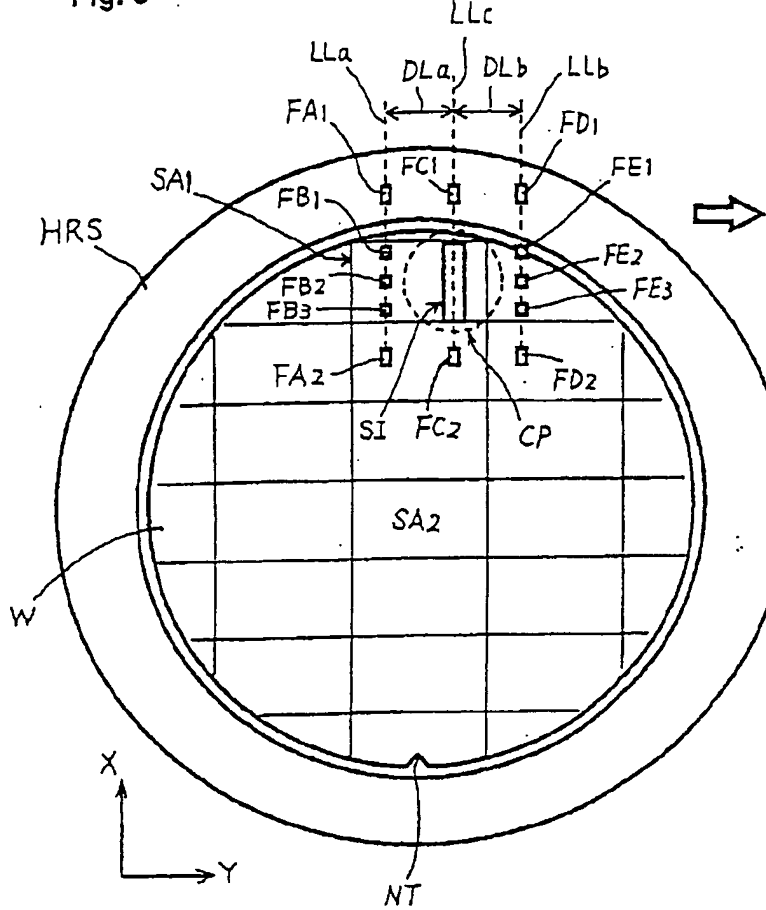

32A
32B
32C
Z-Act.
Z-Act.
Z-Act.
ZC1
ZC2
GDC1
GDC2
35
W-Stage Controller
58
CALCULATE & DRIVE UNIT
52
POSITION MONITOR
SS3
SS2
SS1
56
CALCULATE & MEMORY
ZA1
ZA2
54
CALCULATE
Focus-error
Tilt-error
50
GDA1
GDB1
GDB2
GDB3
GDA2
GDD1
GDE1
GDE2
GDE3
GDD2
GDL
GDR

Fig. 5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LLa
DLa
DLb
LLb
FA1
FD1
FC1
FE1
SA1
FB1
HRS
FE2
FB2
FE3
FB3
FA2
FD2
SI
FC2
CP
SA2
W
X
Y
NT

Fig. 6

Fig. 6A

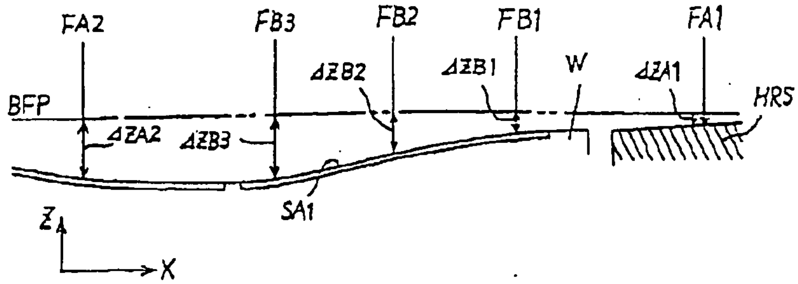


Fig. 6B

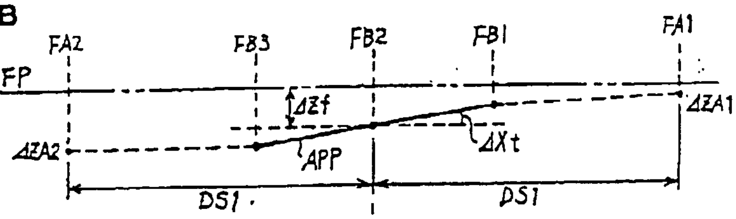


Fig. 6C

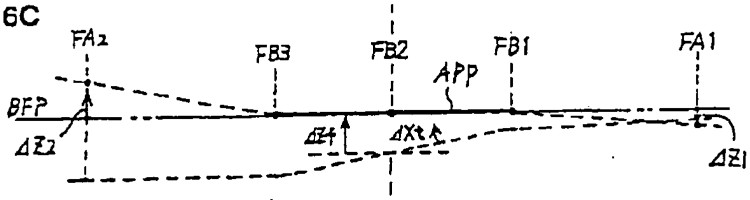


Fig. 6D

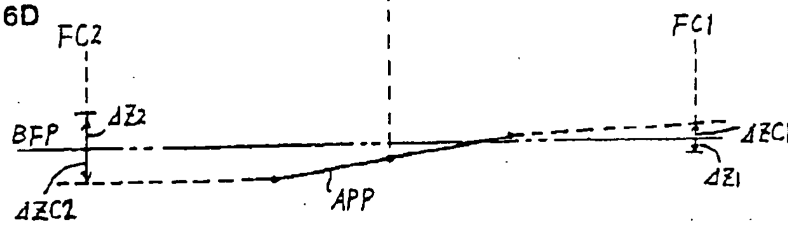
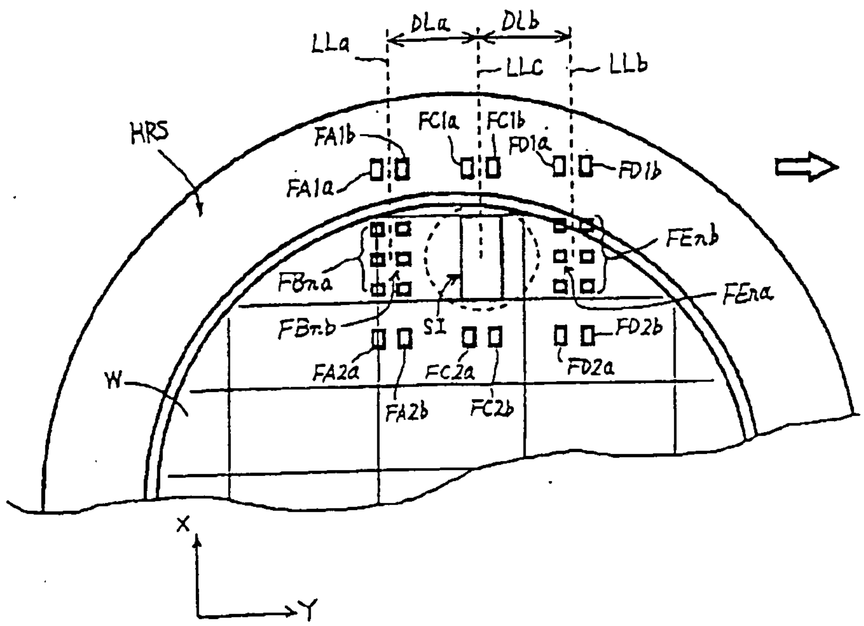


Fig. 7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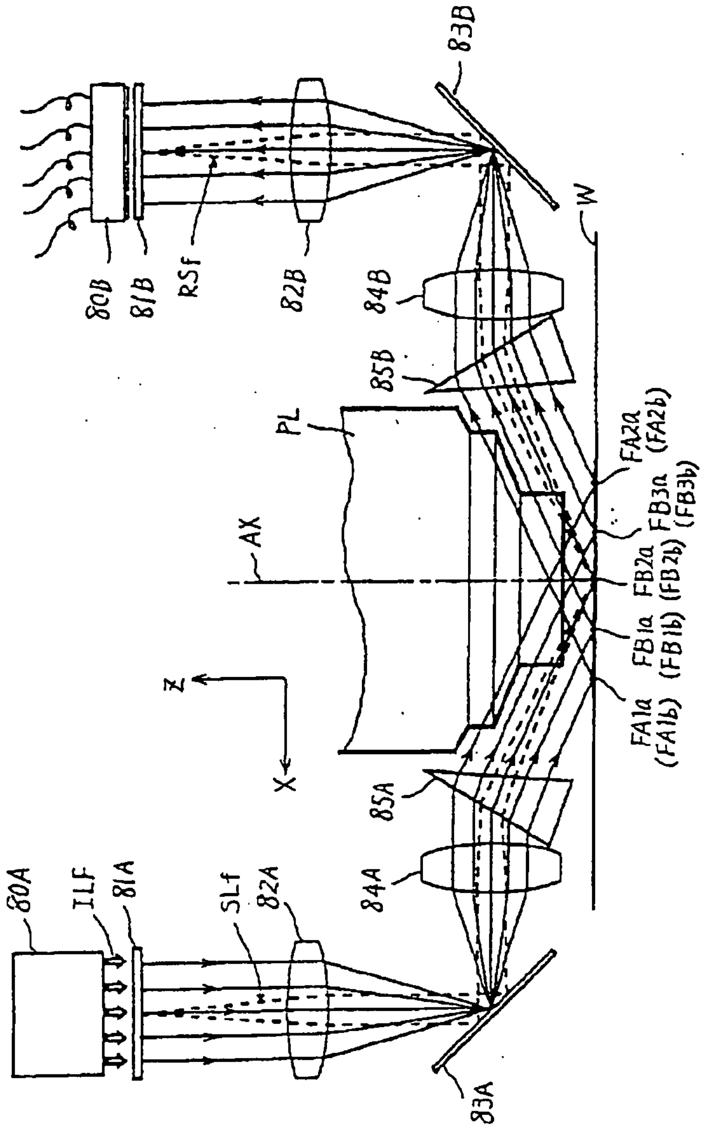
DLb
LLa
LLC
LLb
HRS
FA1b
FC1a
FC1b
FD1a
FA1a
FD1b
FEnb
FBna
SI
FEna
FBnb
FD2b
FA2a
FC2a
FD2a
W
FA2b
FC2b
X
Y

Fig. 8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ILF
81A
SLf
82A
83A
84A
85A
X
Z
PL
AX
FA1a
(FA1b)
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(FB1b)
FB2a
(FB2b)
FB3a
(FB3b)
FA2a
(FA2b)
85B
84B
82B
RSf
81B
80B
83B
W

Fig. 9

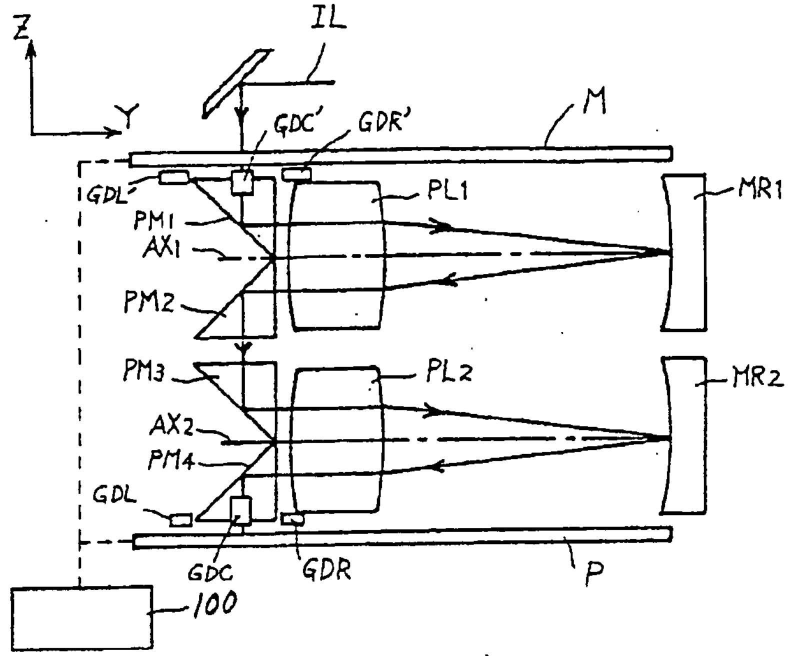

IL
Z
Y
M
GDC'
GDR'
GDL'
PL1
MR1
PM1
AX1
PM2
PM3
PL2
MR2
AX2
PM4
GDL
GDC
GDR
P
100

Fig. 10

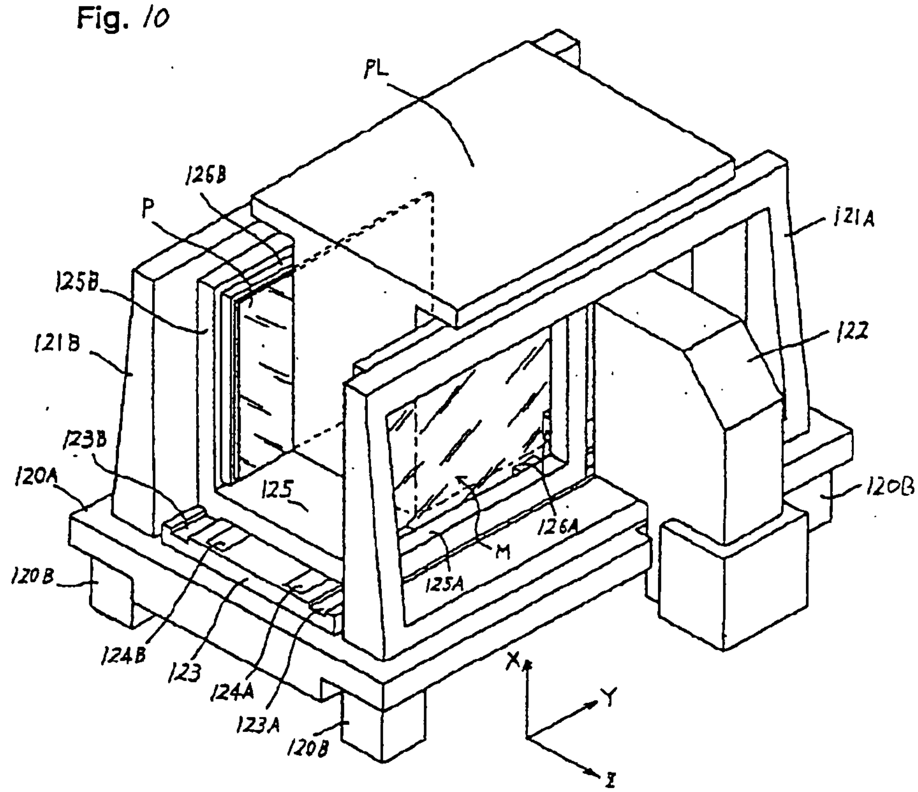
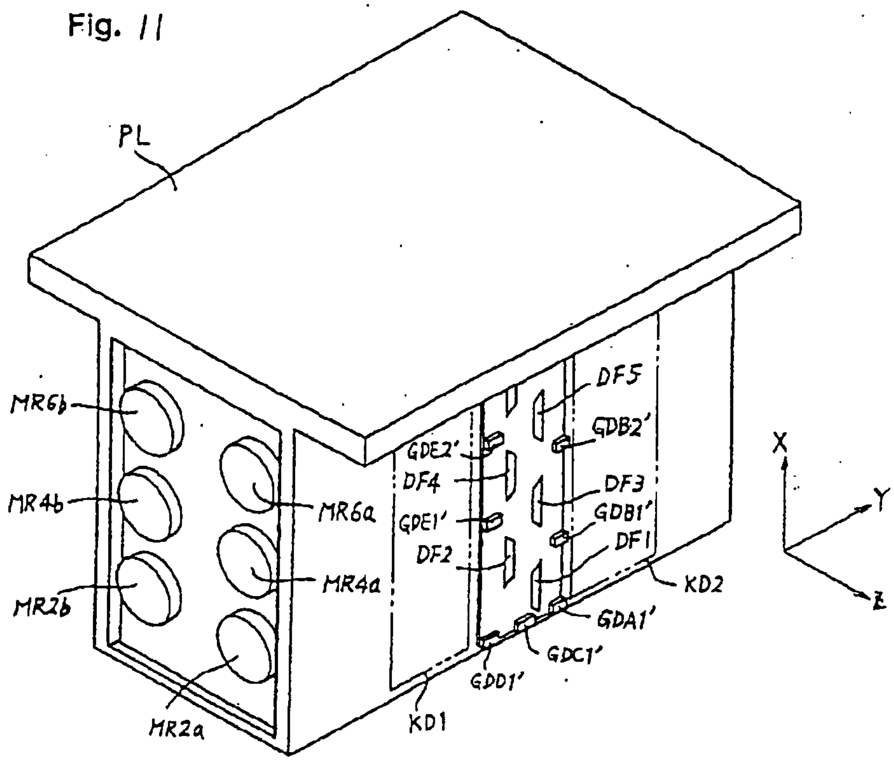

PL
126B
P
125B
121B
121A
122
123B
120A
125
126A
120B
M
125A
120B
124B
123
124A
123A
120B
X
Y
Z

Fig. 11


PL
MR6b
MR4b
MR2b
MR2a
MR6a
MR4a
DF5
GDB2'
GDE2'
DF4
DF3
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DF2
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GDD1'
KD1
X
Y
Z

Fig. 12

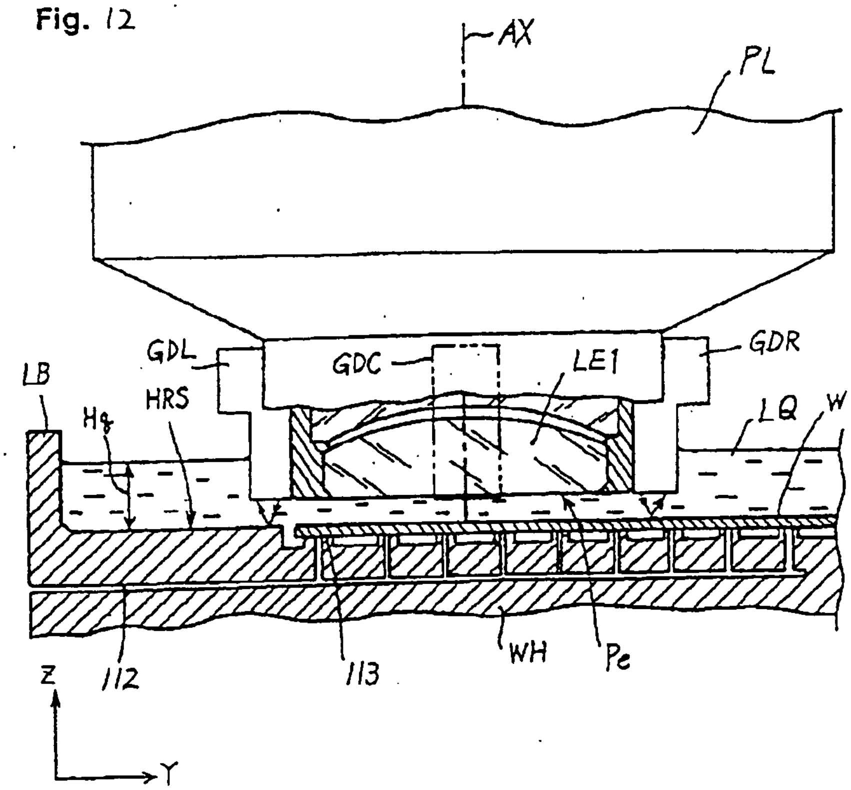

AX
PL
GDL
GDC
LE1
GDR
LB
Hq
HRS
LQ
W
112
113
WH
Pe
Z
Y

Fig. 13

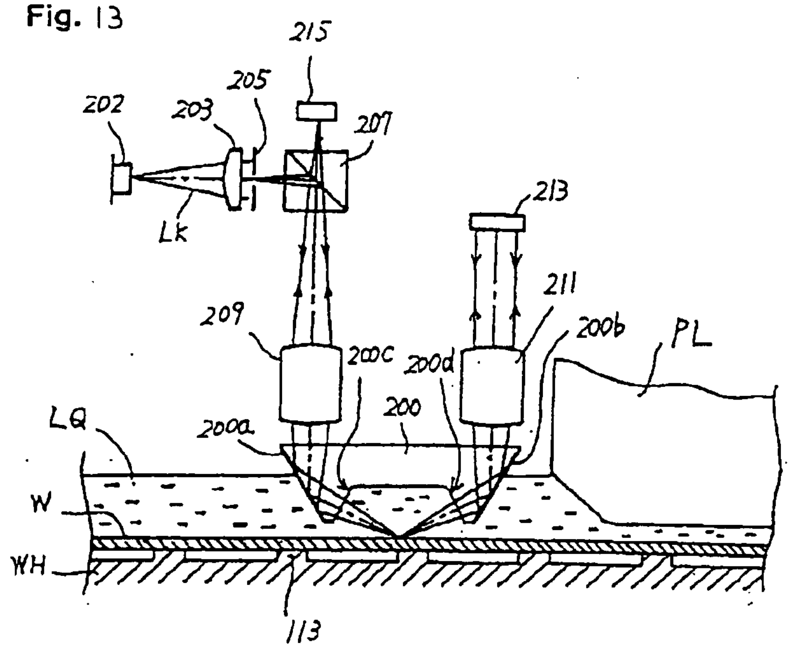


Fig. 14

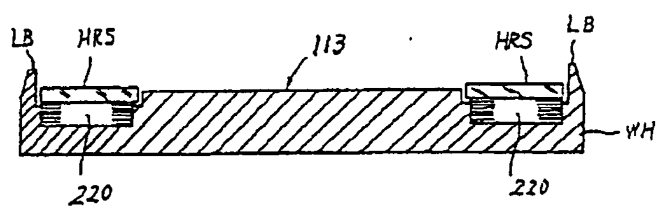


Fig. 15

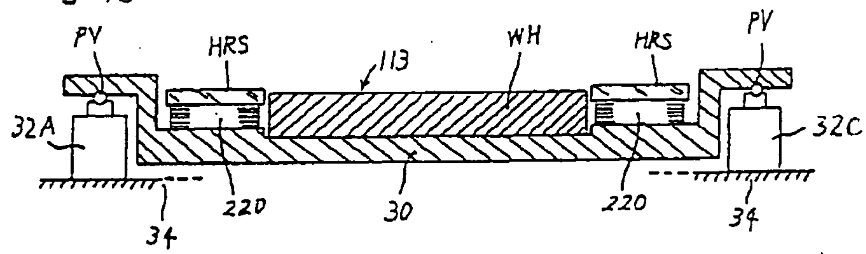


Fig. 16

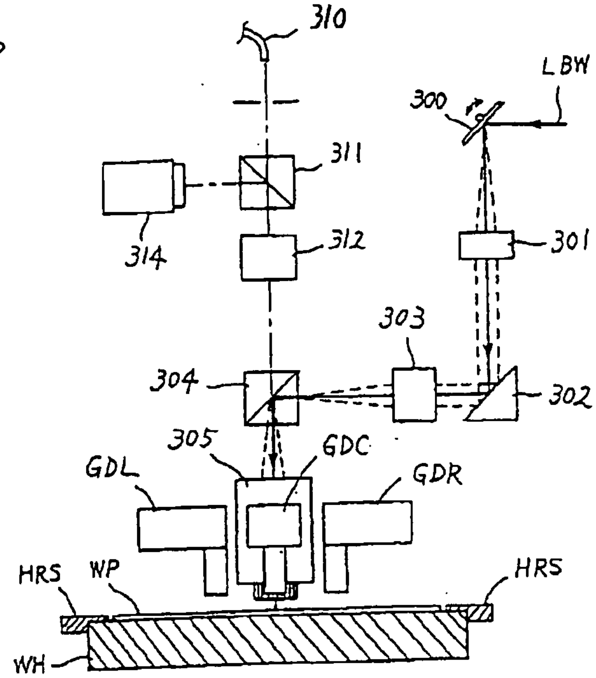
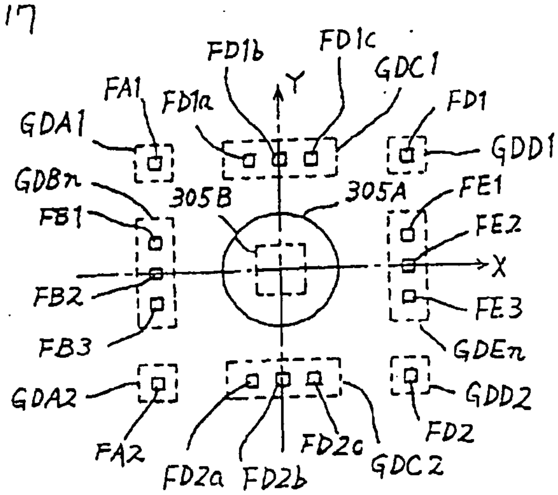

310
LBW
300
311
314
312
301
303
304
302
305
GDC
GDL
GDR
HRS
WP
HRS
WH

Fig. 17


FD1b
FD1c
Y
GDC1
FA1
FD1a
FD1
GDA1
GDD1
GDBn
305B
305A
FE1
FB1
FE2
X
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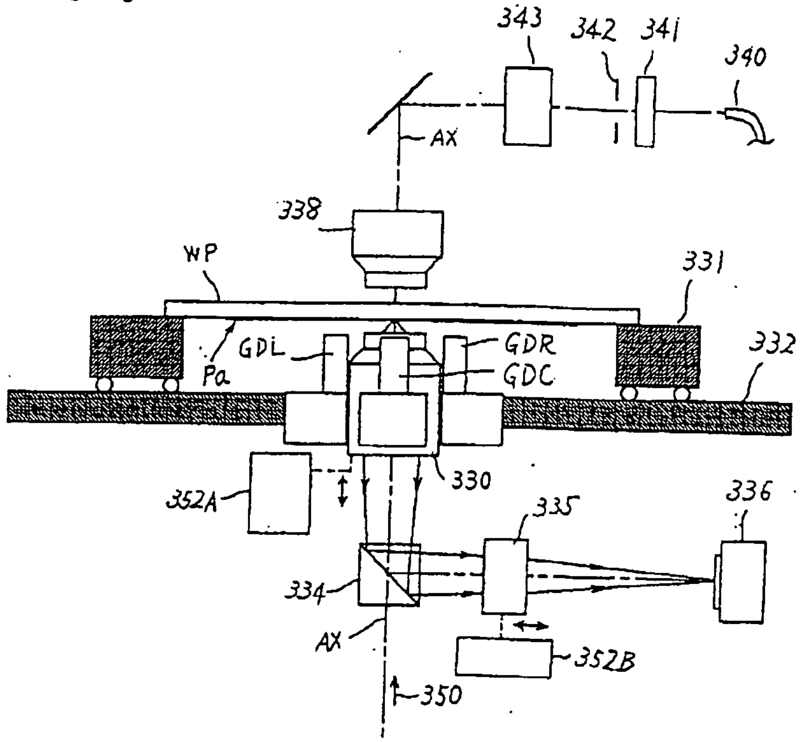
FA2
FD2c
FD2a
FD2b
GDC2

Fig. 18


343
342
341
340
AX
338
WP
331
GDL
GDR
GDC
Pa
332
330
352A
335
336
334
AX
352B
350

1. Abstract

The present invention provides a projection aligner (exposure apparatus) and an exposure method which enable high-precision focusing control and high- precision tilt control even if a projection optical system to reduce the working distance in comparison with the conventional projection optical system is incorporated.

Improvements in a focusing apparatus having an objective optical system for optically manufacturing a workpiece, forming a desired pattern on a surface of a workpiece or inspecting a pattern on a workpiece and used to adjust the state of focusing between the surface of the workpiece and the objective optical system. The focusing apparatus has a first detection system having a detection area at a first position located outside the field of the objective optical system, a second detection system having a detection area at a second position located outside the field of the objective optical system and spaced apart from the first position, and a third detection system having a detection area at a third position located outside the field of the objective optical system and spaced apart from each of the first and second positions. A calculator calculates a deviation between a first focus position and a target focus position and temporarily stores a second focus position at the time of detection made by the first detection system. A controller controls focusing on the surface of the workpiece on the basis of the calculated deviation, the stored second focus position and a third focus position when the area on the workpiece corresponding to the detection area of the first detection system is positioned in the field of the objective optical system by relative movement of the workpiece and the objective optical system.

2. Representative Drawing

Fig. 1